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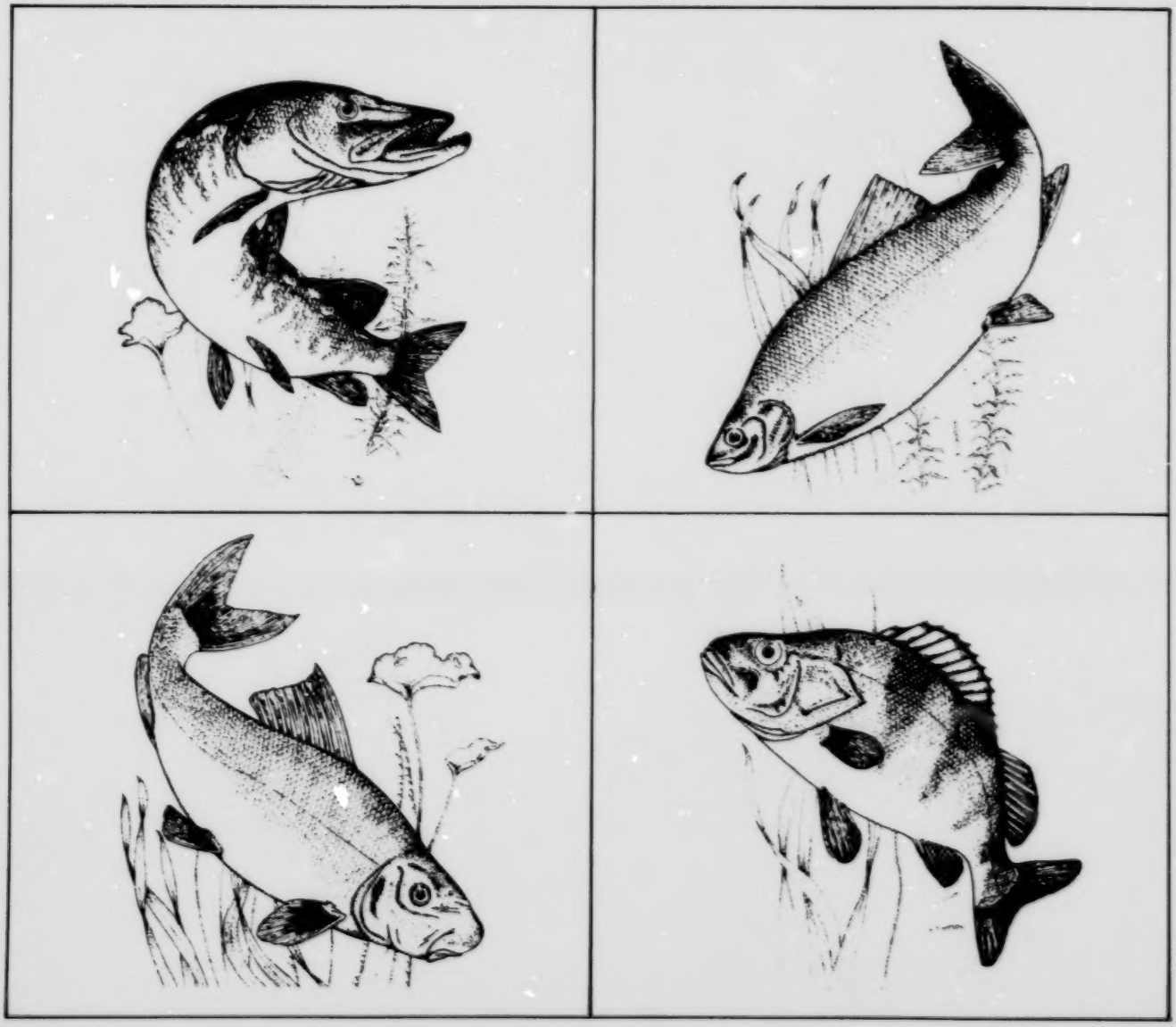
Biological Survey of Smoothstone Lake

Technical Report 90 - 1



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BIOLOGICAL SURVEY OF SMOOTHSTONE LAKE

BY

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EXECUTIVE SUMMARY

A limnological and fisheries investigation was carried out on Smoothstone Lake in the summer of 1988 by the Fisheries Branch, Saskatchewan Parks, Recreation and Culture. The objectives of the study were to prepare a bathymetric map, to obtain data on the physico-chemical characteristics and biota of the lake, and to identify reasons for the apparently low productivity of fish in the lake.

Smoothstone lake is located just east of Dore Lake approximately 240 km northwest of Prince Albert and is road accessible. It has an area of 284 km^2, a maximum length of 26 km and a maximum depth of 33 m. It is situated on boreal glacial deposits and is part of the Churchill River drainage. The lake has few islands and is exposed to wind action which prevents thermal stratification. Water quality characteristics are typical of lakes in the forest zone with total dissolved solids ranging from 238 to 264 mg/L and pH between 8.0 and 8.3.

The plankton community is dominated by blue-green algae with diatoms and green algae appearing predominantly in the spring and fall. Average crop of plankton was substantially higher than in other large lakes in the area. Midge larvae are the predominant organisms found in the bottom sediments of Smoothstone Lake. These provide the main food resource for whitefish.

Seventeen species of fish were collected during the study. Yellow perch, spottail shiners, ninespine sticklebacks, emerald shiners and fathead minnows were the most common small forage fish species. White and longnose suckers and perch made up 77 per cent of the total numbers of fish caught in gill nets. Other species caught were whitefish (14.4%), cisco (9.8%), northern pike (3.4%) and burbot (0.5%). Only 1 walleye was caught in 28 netsets. Gillnets caught an average of 163 fish per net set consisting of 300 yards of net made up of 6 different mesh sizes. Almost 85% of the fish caught were taken in the three smallest mesh sizes ranging from 3.8 to 7.6 cm.

Northern pike is the dominant sport fish species but represents only 3.4% of the large fish species in Smoothstone Lake. Walleye are scarce. Whitefish are the most abundant commercial fish species. Ages of this species ranged from 1 to 30 years with the majority in the 5 year class. The whitefish are infested with *Triaenophorus* cysts and are presently classed as cutters. Ciscoes, yellow perch and various minnow species provide a plentiful food source for larger fish such as pike and walleye.

The fish resource in Smoothstone Lake is used by a commercial fishery, a small itinerant sport fishery and a one person domestic fishery. There are no active outfitters on the lake. The lake also supports a small rainbow trout cage culture operation. The commercial quota is presently set at 56 700 kg including pike, whitefish and walleye. The legal mesh size is 12.7 cm. Commercial production has

declined to less than 10 000 kg in recent years due primarily to lack of a market for cutter whitefish.

Angling activity on Smoothstone Lake is very limited with northern pike being the predominant catch. Absence of walleye and the inhospitable nature of the large open lake contribute to the poor angling opportunity. Sport fish numbers appear to be limited by lack of suitable spawning and nursery areas rather than availability of food.

Estimated sustained yield of all species of fish using two methods of calculation based on water quality is approximately 4.9 kg/ha/yr. Total production in Smoothstone Lake is estimated at 78 344 kg per year including 48 408 kg of whitefish and 29 936 kg of pike.

The following management strategies are recommended to maximize whitefish harvest, to provide a fair allocation of northern pike resources, and to re-establish the walleye population:

1) The annual commercial fishery quota should remain at 56 700 kg/yr with separate quotas of 45 700 kg for whitefish and 11 000 kg for northern pike thus allocating 18 000 kg of northern pike for angler harvest.

2) A zero tolerance for walleye in the commercial harvest should be imposed to help restore the walleye population. The harvest of pike should be fixed at a maximum of 20% of the total catch.

3) A reduction in mesh size to 11.4 cm is recommended to facilitate the harvest of whitefish. This should stimulate the growth of the whitefish present.

4) A reassessment of *Triaenophorus* infestation in whitefish should be undertaken to confirm reduced infestation levels found in this study with the possibility of reclassifying the lake to provide better market advantage for whitefish.

5) An angling quota of 3 walleye per day should be introduced to allow the population to improve.

6) An inventory of spawning habitats should be prepared. Spawning streams should be cleared of obstructions such as beaver dams and improperly placed culverts to aid in the establishment of walleye and improve the production of northern pike.

7) A reassessment of the fish population should be undertaken in 5 years to evaluate the results of the management strategy.

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1. INTRODUCTION

A limnological and fisheries investigation of Smoothstone Lake was carried out from May 24 to August 22, 1988 by the Saskatchewan Fisheries Laboratory, Fisheries Branch, Saskatchewan Parks, Recreation and Culture. With the exception of brief investigations of the lake in 1956 (Scott, Unpublished) and 1976 (Walton 1977), no fisheries information was available for Smoothstone Lake until the present survey was conducted. Objectives of the study were to produce a bathymetric map, to obtain data on the physico-chemical characteristics, and to carry out a biological survey of the net-plankton, bottom fauna and fishes of the lake, and to identify reasons for the apparently low productivity of fish in this lake. Information gathered was integrated with earlier data and used to estimate potential productivity, sustained yields, and population trends; make recommendations on fishery utilization programs; and provide background information.

2. DESCRIPTION OF STUDY AREA

Smoothstone Lake (54°40' 106°50') is situated in central Saskatchewan approximately 240 km northwest of Prince Albert (Fig. 1). The lake is road accessible via secondary roads from Highways 2 or 55. The lake lies on mainly sedimentary rocks consisting of sandstone, siltstone and shale (Richards and Fung 1969). Natural vegetation of the land surrounding Smoothstone Lake is mixed wood forest, dominated by

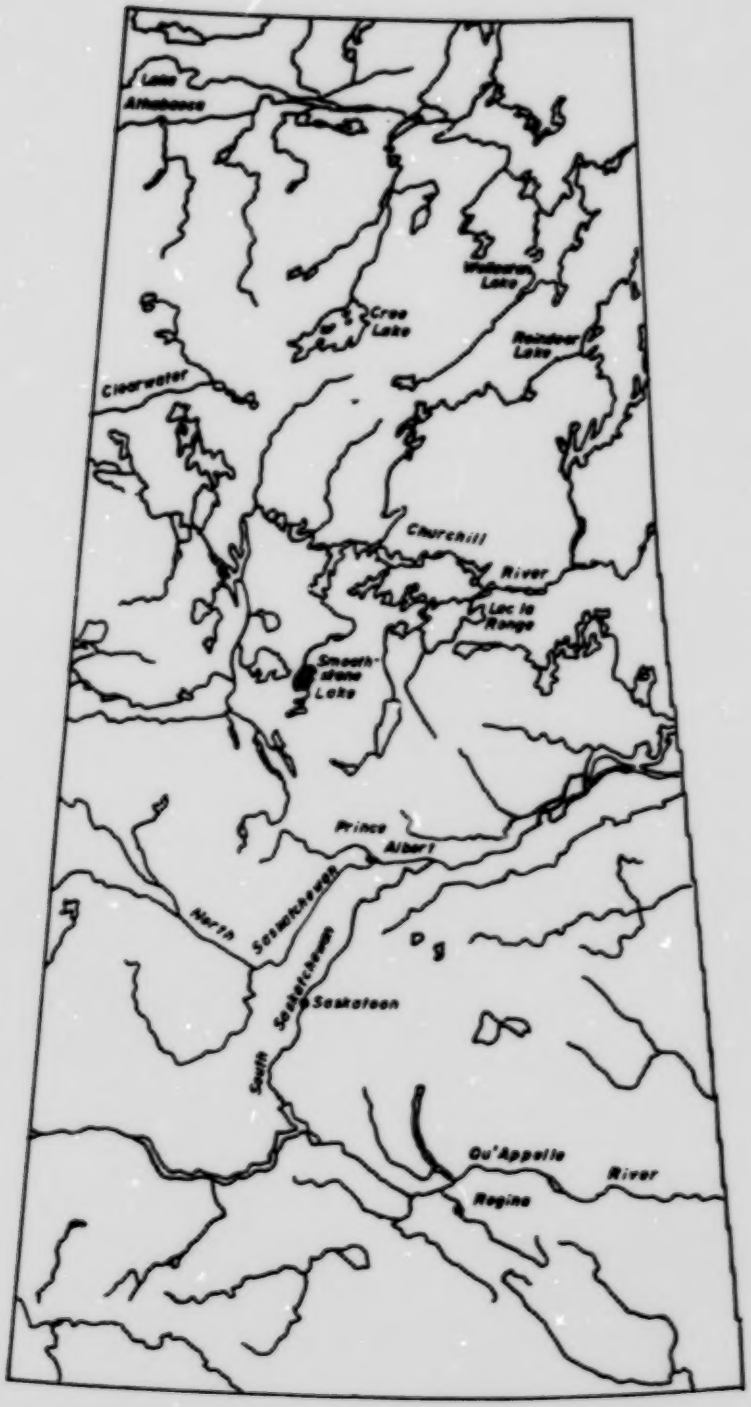

Fig. 1 Map showing the location of Smoothstone Lake.

aspen and white spruce. Black spruce and larch are common in the low lying areas. Topography of the area is moderately rolling to hilly.

Inflow to Smoothstone Lake is from three main tributaries. Mahigan Creek flows westward into Selenite Bay in the northeastern portion of the lake and drains Mahigan Lake as well as several smaller headwater lakes. Philion River flows into the east side of the lake and drains Philion, Little Philion and Hurtean Lakes. Drainage provided by both these streams is intermittent and dependent on local runoff conditions. During the summer months the streams become obstructed by beaver dams. The major inflow is from Smoothstone River, which drains several waterbodies to the south of Smoothstone Lake, including Wabeno, Lavallee, Paquin, Listen and Clarke Lakes, and Nitawanga Creek. The Smoothstone River flows into the southeastern portion of Smoothstone Lake and exits at the north end of the lake, providing the only outflow. It empties into the Churchill drainage by way of Pinehouse Lake. The total drainage area for Smoothstone Lake is approximately 2900 km^2.

Smoothstone Lake is roughly circular in shape and has only three islands. The large expanse of open water (284 km^2) and lack of islands offer little protection from prevailing winds. Shelter Island, with an area of <4 km^2, is the only island of significant size.

A provincial campground exists on the southwest corner of the lake. Facilities available are basic, consisting of a non-designated camping area, outhouses, a fish filletting table and a boat dock. A private hunting and fishing lodge operates on the west side of

Smoothstone Lake. Construction of a new lodge has been proposed for the near future and inquiries have been received about others. The nearest community is Dore Lake, a center of approximately 100 people.

Two seasonal residences are located on the lake. The occupant of one is a resident commercial fisherman who also operates a small rainbow trout cage culture operation on the lake.

Available records show that a commercial fishery has operated on Smoothstone Lake at least since 1925. Species of fish taken by the fishery are primarily northern pike and lake whitefish. Small quantities of walleye have also been harvested. Since 1952, the commercial quota has been set at 56 700 kg, with 22 700 kg being harvested during the summer season and the remaining 34 000 kg taken during the winter. No special quotas are in effect to protect the gamefish species. The legal mesh size has remained unchanged at 12.7 cm since 1952, although commercial fishermen in the mid 1970s requested that the mesh size be lowered to 11.4 cm.

A small amount of sport fishing occurs on Smoothstone Lake. Over the course of the study, only about 30 anglers were observed fishing on the lake. Most of the anglers were residents in communities within 200 km of Smoothstone Lake, such as Debden and Big River.

3. METHODOLOGY

Field investigations began May 25 and were completed August 22, 1988. The study alternated between 10 days in the field and 4 days out.

The lake was sounded with an echo sounder (Furuno model FE-400) to obtain depth profiles of the lake basin. Thirty-five sounding transects were taken over the course of the summer, primarily during the first two weeks of June. Sounding transects were marked on a large scale map prepared from 1:50 000 topographic maps and depth contours plotted. The area in each depth zone was measured from the work map, using a dot area grid. Total water area and volume were then calculated. Shoreline length was measured from the work map using a map measurer. A reference bench mark for water levels was installed on the point of land in the D. Adderly acreage (see Fig. 2 for location). The bench mark is a brass cap stamped June 14, 1988: S.P.R.C. Fisheries Branch.

Field measurements of physico-chemical conditions were made at two measuring points on a bi-weekly basis beginning on May 25, 1988. Station A was located in the west central portion of the lake (Fig. 2). Station B was located between Shelter Island and the north shore of the lake. Water temperature and dissolved oxygen profiles were obtained using a temperature-dissolved oxygen meter (YSI model 57). pH measurements of surface and bottom water samples were obtained

Fig. 2 Bathymetric map of Smoothstone Lake.

colourimetrically with a Hellige pocket comparator. Transparency was measured with a Secchi disc, 20 cm in diameter.

Water samples were collected with a Kemmerer water sampler from both the surface and bottom and stored in 2 L plastic bottles for chemical analyses. The water samples were filtered immediately upon collection, using Gelman Type A-E glass fibre filters and a hand operated vacuum pump. The filtered water was refrigerated. Bottom samples from stations A and B, and composite surface samples were sent to the provincial laboratory for analysis of major chemical parameters. The filters were put into labelled envelopes and refrigerated for chlorophyll analyses. Chlorophyll was extracted from the filters in the laboratory using acetone. Levels of chlorophyll a were measured using a spectrophotometer (Bausch and Lomb Spectronic 88), following the method of Lorenzen (1967).

Total plankton biomass was measured by collecting total vertical hauls with a 25 cm Wisconsin plankton net made of No. 20 bolting silk (80 µ pore size). The samples were dried, weighed and then ashed (600°C) to obtain dry weight and percentage of mineral matter. The net efficiency was determined by straining representative samples of water through the net and comparing the weight of the biomass collected with that collected when the net is drawn through a 10 metre vertical column. Vertically integrated plankton samples were collected with a Tygon™ tube (30 m x 1.25 cm I.D.) and preserved with Lugol's solution

for species identification and enumeration. Identification and counts were made on 10 mL aliquots, using an inverted microscope.

Benthic samples were collected with a 500 cm^2 Ekman dredge. Thirteen series of 6 grab samples were taken throughout the lake. The samples were washed through a set of 3 screens, the finest having 11 meshes/cm. Organisms collected from the screens were preserved in 70% alcohol for identification, enumeration and weighing in the laboratory. Dry weight was assumed to be 12% or 15% of wet weight, depending on whether midge larvae (Chironomidae) or amphipods dominated the sample.

Large fish were collected using standard gangs of gill nets comprised of 46 m each of 3.8, 5.1, 7.6, 10.2, 12.7 and 14.0 cm meshes tied in series. Nets were bottom set in 26 locations throughout Smoothstone Lake in representative types of habitat during the summer, beginning May 31, 1988. The nets were set for a period of 24 hr before being lifted. All fish caught in them were removed for analysis.

All fish captured in the gillnets were enumerated and weighed. Sport and commercial fish species were measured (fork length); sex and state of maturity were noted; and stomach contents were examined. Ageing materials including scales, otoliths and cleithra were collected from walleye, northern pike, lake whitefish and burbot. Ten fish per cm length interval were selected for ageing from each species. Usually two ageing media were taken from each fish. Techniques used for ageing fish are described by Musker (1985). Individual lengths and weights of a representative sample of rough fish species (white sucker,

longnose sucker, cisco and yellow perch) were taken. After 100 fish of a species had been analyzed, maximum and minimum lengths and total numbers and total weights of remaining fish were recorded.

Beach seining was used to collect minnows and juveniles of larger fish species. These fish were preserved in 10% formalin for enumeration and identification in the laboratory.

Fish captured by the commercial and sport fisheries were examined periodically throughout the summer and measurements of lengths and weights were taken.

4. RESULTS

4.1 MORPHOMETRIC AND PHYSICO-CHEMICAL FEATURES

4.1.1 Morphometric Features

Bathymetric mapping of the bottom profile of Smoothstone Lake was completed to replace the hand sounded bathymetric maps prepared by Scott in 1956 (See Fig. 2). The depth contours were used to calculate lake volume, volume in depth strata at 5 m intervals, mean depth and maximum depth. Various morphometric features of Smoothstone Lake are presented in Table 1. A permanent bench mark was established on a peninsula near the public campground. Water level at the time of sounding was 1.4 m below the bench mark.

Table 1. Morphometric features of Smoothstone Lake, 1988.

Depth zones, m	Area		Lake volume
	km^2	%	x 10^3 m^3
0-5	49.78	17.5	1 294 290
5-10	57.27	20.2	1 026 685
10-15	73.97	26.1	698 598
15-20	61.23	21.6	360 610
20-25	37.81	13.3	113 013
25-30	2.37	0.8	12 555
>30	1.33	0.5	1 989
Total			
Water area	283.75		3 507 740
Island area	3.93		
Lake area	287.68		

Mean depth, m	10.0
Maximum depth, m	33.0
Maximum length, km	26.3
Shoreline length, km:	
Excluding islands	130.5
Including islands	147.4
Shore development:	
Excluding islands	2.2
Including islands	2.5

Smoothstone Lake has a total water area of 283.8 km^2 and a volume of 3507.7 x $10^6 m^3$ as determined from topographic maps. Its maximum length is approximately 26 km and lies in a northeast-southwest direction. The lake is almost circular in shape. Only three islands occur in the lake. The largest island, Shelter Island, has an area of 3.8 km^2. Mean and maximum depths were determined to be 10.0 m and 33.0 m, respectively. Over 85% of the lake overlies depths <20 m.

Shore development (the ratio of the length of the shoreline to the length of the circumference of a circle of area equal to that of the lake), including islands, is 2.5. This value is similar to Dore Lake (2.8) but is much lower than typical shield lakes such as the Foster Lakes (18.3) (Dean 1980). This reflects the potential for development of littoral communities in proportion to the volume of the lake (Wetzel 1975). The larger the shore development the larger the amount of littoral habitat available for production of forage fish and larger sport fish species including pike, yellow perch and walleye.

4.1.2 Temperature

Breakup on Smoothstone Lake occurred approximately May 12, 1988. The open water season generally extends to about mid-November.

In the course of the study, surface water temperatures at station A in the west-central area of the lake varied from a minimum of

10.0°C on May 25 to a maximum of 18.0°C recorded on July 22 (Appendix 1). Surface water temperatures at Station B, in the northern portion of the lake, ranged from 8.5°C on May 26 to 19.0°C on July 22 (Appendix 2). Variations in surface water temperatures between the two stations are due to differences in dates and times of measurements.

Bottom temperatures at station A varied from a minimum of 5°C on May 25 to a high of 12.0°C on August 4 and August 17. Bottom waters at station B ranged between 5.0°C on May 26 to 13.5°C on August 4 and August 18. Vertical profiles of temperature (Appendices 1 and 2; Fig. 3) indicate that persistent, well-defined thermal stratification did not develop in Smoothstone Lake during the study period. The change in the thermal gradient was generally not more than 1°C per metre. Lack of a stable thermocline indicates that Smoothstone Lake is relatively well-mixed during the summer months.

4.1.3 Dissolved Oxygen

Dissolved oxygen concentrations in the surface waters of Smoothstone Lake ranged from 8.0 mg/L (83% saturation) to 13.6 mg/L (126% saturation) at station A (Appendix 1). Oxygen concentrations gradually decreased from surface to bottom waters. Dissolved oxygen in the bottom waters varied between 0.3 mg/L (3% saturation) on August 18 at station B and 13.2 mg/L (108% saturation) on May 25 at station A. Generally, dissolved oxygen levels in Smoothstone Lake were adequate to support fish populations except for the near bottom waters.

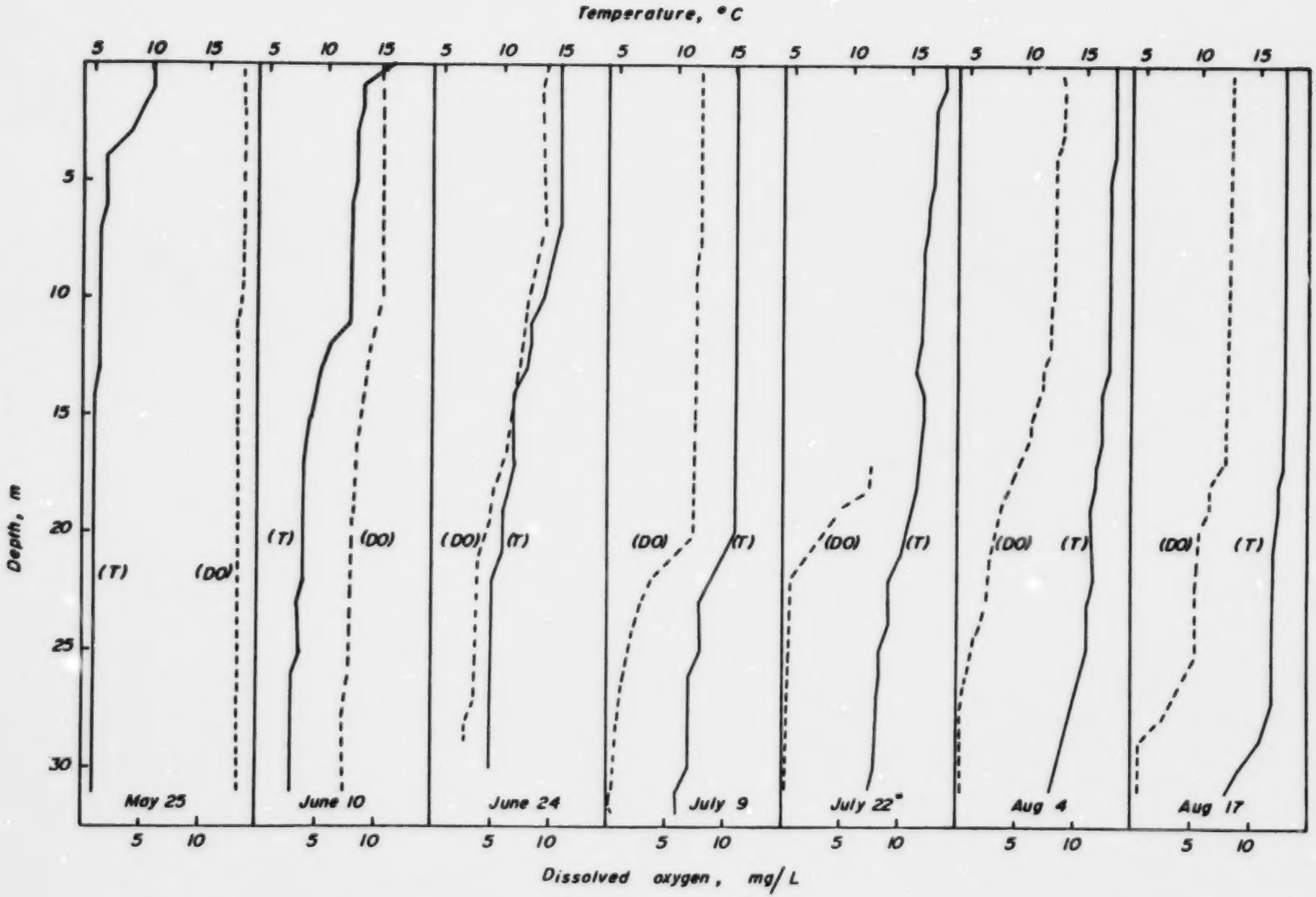

Fig. 3 Oxygen (DO) and temperature (T) profiles at station A, Smoothstone Lake, 1988.

** Oxygen meter malfunctioning.*

Dissolved oxygen levels at both stations decreased during the spring as temperatures increased, then remained relatively constant throughout the summer (Appendices 1 and 2; Fig. 3).

4.1.4 pH and Transparency

Surface water pH of Smoothstone Lake varied between 8.0 and 8.3. Bottom waters were less alkaline, ranging from 7.3 to 8.1 (Appendices 1 and 2). A reduction in pH of the bottom waters in Smoothstone Lake is due to a combination of biologically-mediated reactions (decompositional processes, and respiratory generation of carbon dioxide in the sediments) and is a natural occurrence in temperate zone lakes (Wetzel 1975).

Secchi disc transparency ranged from 1.5 m on August 4 at station B to 4.0 m on May 25 at station A (Appendices 1 and 2). Average values were 2.8 m at station A and 2.4 m at station B. Generally, transparency tended to decrease as summer progressed.

4.1.5 Water Quality

Results of water analyses for five bottom samples from each of the stations on Smoothstone Lake and seven composite surface samples are given in Table 2. There was little difference in levels of chemical parameters measured in the water samples collected between stations, between surface or bottom, or during the course of the summer.

Table 2. Chemical analyses of water from Smoothstone Lake, 1988. All values except pH and conductivity are given in mg/L.

	Station A (bottom)					Station B (bottom)					Stations A & B combined (surface)						
	June 10	June 24	July 8	July 22	Aug 17	June 24	July 8	July 22	Aug 4	Aug 18	May 25	June 10	June 24	July 9	July 22	Aug 4	
TDS*, calc.	240	243	244	250	264	244	239	246	243	241	238	240	238	239	240	238	
Bicarbonate (HCO_3)	186	187	188	190	205	187	185	187	186	187	183	185	184	184	185	185	
Chloride (Cl^-)	<2	<2	<2	2	<2	2	<2	2	2	<2	2	<2	<2	<2	<2	<2	
Sulphate ($SO_4^{=}$)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	
Calcium (Ca^{++})	31	32	33	34	33	34	31	33	34	32	31	31	31	31	34	33	
Magnesium (Mg^{++})	17	17	16	17	19	16	17	18	16	16	17	18	17	18	16	15	
Sodium (Na^+)	6	6	7	7	7	6	6	6	6	6	6	6	6	6	6	6	
Nitrate (NO_3)	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Total alkalinity (as $CaCO_3$)	152	153	154	156	168	153	152	154	152	153	150	152	151	151	151	151	
Total hardness (as $CaCO_3$)	147	153	148	154	161	148	147	154	150	148	147	152	147	150	150	143	
Iron	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0
Manganese	0.01	0.08	0.27	0.83	3.70	0.06	0.01	0.01	0.01	0.09	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.
Conductivity, µ s/cm	240	260	235	235	280	250	228	253	250	250	250	280	250	225	224	250	2
pH	8.1	7.9	8.1	7.7	8.1	8.0	8.0	7.8	8.1	8.0	8.0	8.2	8.3	8.1	8.3	8.3	8

* Total dissolved solids

Total dissolved solids determined as the sum of major ions, ranged from 238 - 264 mg/L.

Total alkalinity of Smoothstone Lake ranged from 150 - 168 mg/L. With an average total alkalinity of 154 mg/L, Smoothstone Lake is typical of lakes in the forest zone as described by Liaw and Atton (1981). Lakes in the forest zone usually have alkalinities ranging between 11 - 237 mg/L. Total hardness levels in Smoothstone Lake varied between 143 - 161 mg/L. Hardness of water is primarily determined by the sum of the calcium and magnesium ions, although other minor constituents may contribute to hardness levels.

Several parameters (sulphate, chloride, iron and manganese) could not always be measured because concentrations were below the detection limits of the analytical procedure.

4.2 PLANKTON

Results of qualitative examination of plankton from stations A and B in Smoothstone Lake are given in Appendix 3. Phytoplankton made up the bulk of plankton collected. Abundance of phytoplankton at both stations increased throughout the summer months (Fig. 4) with highest populations in terms of numbers/L occurring in mid-August. At station A, populations increased from 22.1 cells x 1000/L in May to a maximum of 41.9 cells x 1000/L in mid-August. Plankton populations at station B increased from 21.1 cells x 1000/L in May to 57.1 cells x 1000/L in August.

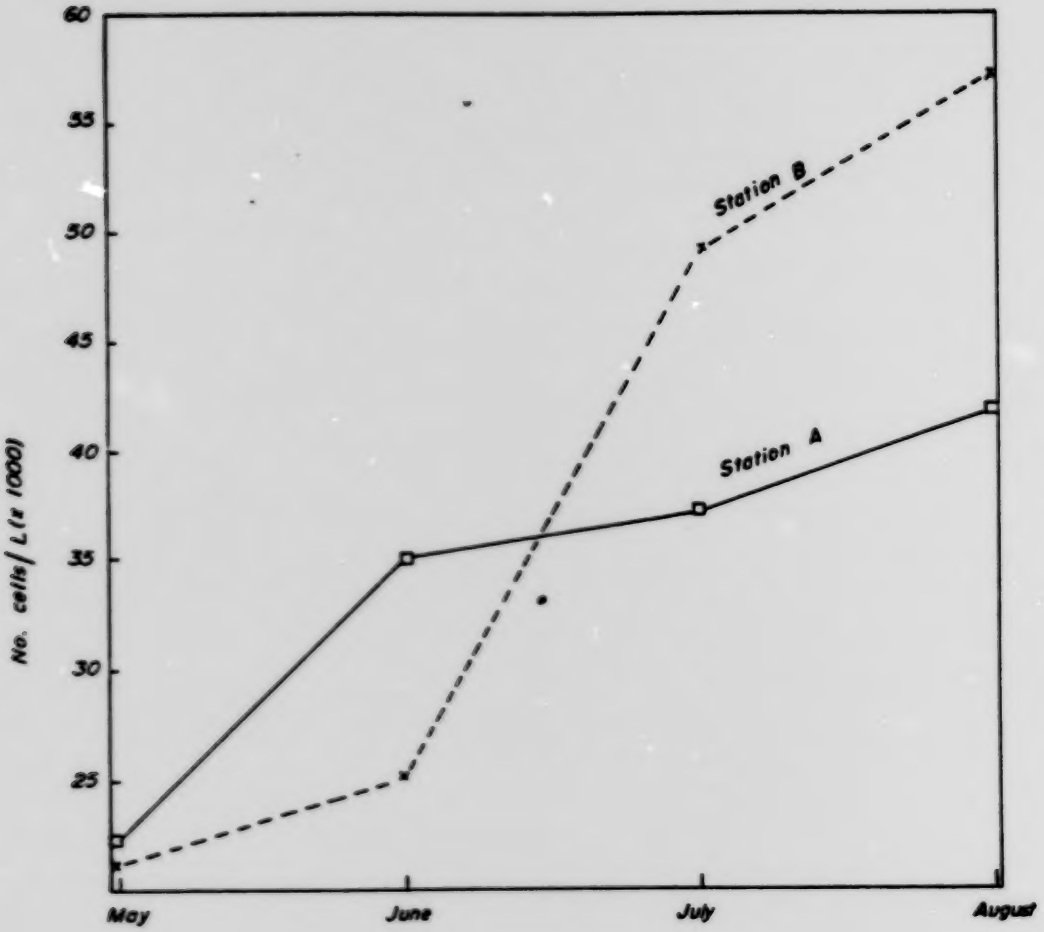

Fig. 4 Abundance of phytoplankton at stations A and B, Smeathstone Lake, 1988.

Blue-green algae were dominant at both stations throughout the summer months (Fig. 5). Diatoms were ranked second in abundance at station B during May and June, followed by green algae. In July and August, this trend was reversed, with green algae ranking second and diatoms third. At station A, diatoms and green algae were almost equally abundant.

Microcystis aeruginosa was the dominant blue-green species at both stations, generally making up at least 50% of the total number of Myxophyceae. Other abundant species of blue-green algae consisted of *Coelosphaerium naegelianum* and *Anabaena flos-aquae*. *Fragilaria crotonensis* was the most abundant diatom in Smoothstone Lake. Other diatoms, *Melosira granulata*, *Stephanodiscus astrea* and *Tabellaria fenestrata* were also common. *Pediastrum boryanum* and *P. duplex* were the dominant species of green algae occurring in Smoothstone Lake.

Golden algae, euglenoids and dinoflagellates contributed only a small proportion of the phytoplankton.

Quantitative analysis of net-plankton at stations A and B on Smoothstone Lake is given in Table 3. Plankton production ranged from 20.9 kg/ha on May 26 at station B near the north end of the lake to 149.2 kg/ha on July 7 at station A. At both stations, plankton biomass was greatest in July, the peak of the growing season. Average standing crop of plankton at station A (102.1 kg/ha) was more than twice that at station B (38.2 kg/ha).

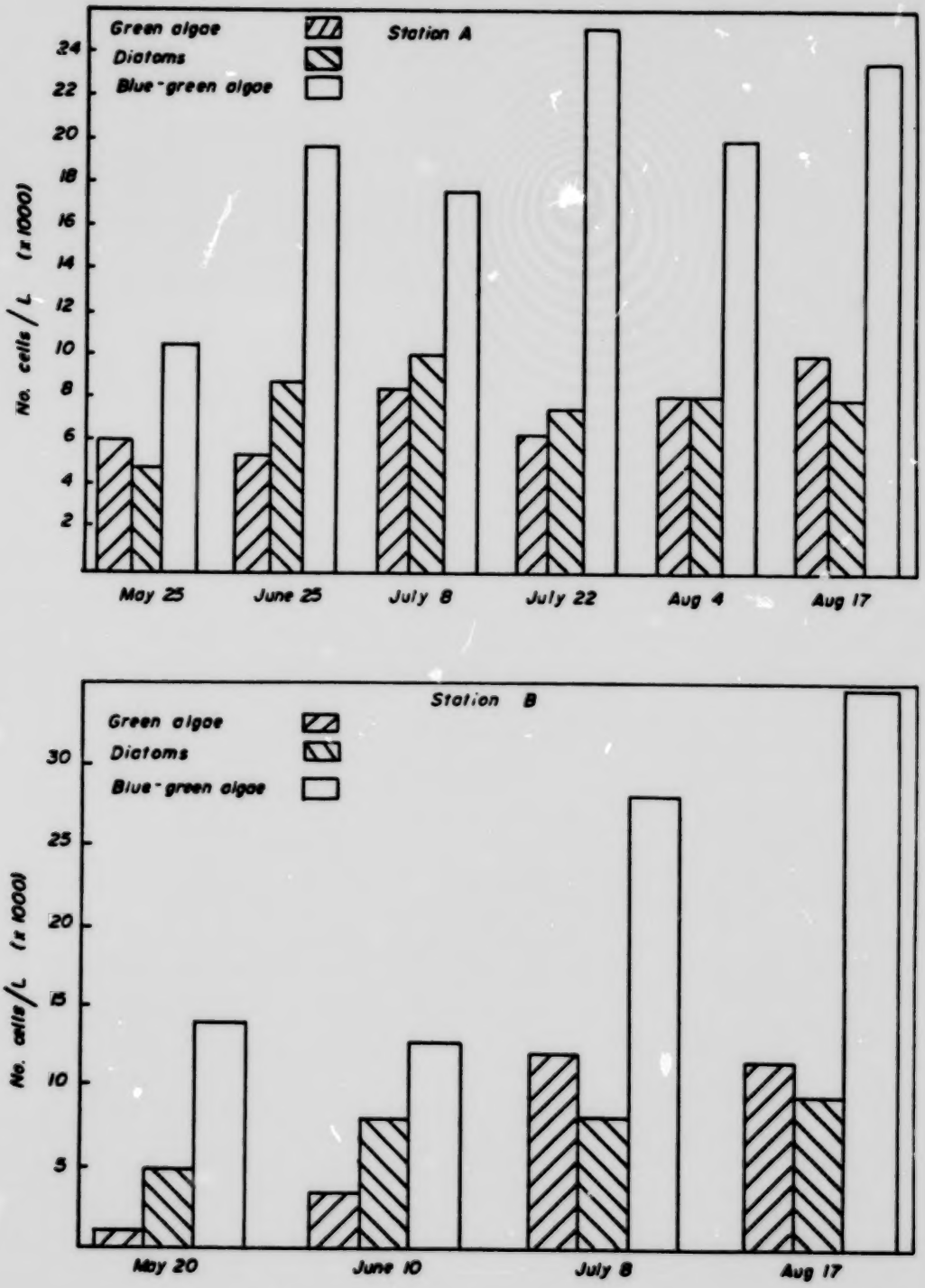

Fig. 5 Seasonal distribution of phytoplankton at stations A and B, Smoothstone Lake, 1988.

Table 3. Quantitative analysis of net-plankton at stations A and B, Smoothstone Lake, 1988 (corrected for net efficiency of 40.9%).

Date	Station	Weight TVL, g*	% Ash	kg/ha
May 25	A	0.1080	38.1	53.9
June 10	A	0.1536	47.7	76.6
June 24	A	0.1891	43.6	94.3
July 7	A	0.2992	32.8	149.2
July 22	A	0.1806	44.2	90.0
August 4	A	0.2096	33.6	104.5
August 17	A	0.2934	29.2	146.3
Mean ± standard deviation		0.2048 0.0650	38.5 6.4	102.1 32.4
May 26	B	0.0420	23.1	20.9
June 10	B	0.0826	38.7	41.2
June 24	B	0.0813	28.0	40.5
July 7	B	0.0949	36.0	47.3
July 22	B	0.0863	34.5	43.0
August 4	B	0.0732	27.7	36.5
August 17	B	0.0756	25.4	37.7
Mean ± standard deviation		0.0766 0.0156	30.5 5.5	38.2 7.8

* TVL: total vertical lift

The higher plankton standing crop at station A, in the west central portion of Smoothstone Lake suggests higher nutrient loadings, probably from the inflowing Smoothstone River which drains watersheds to the south in which extensive pulp wood harvesting has been taking place.

Ash content varied from 23.1 - 47.7%: average ash content at stations A and B was similar, at 38.5% and 30.5%, respectively. Ash content reflects levels of diatoms more than blue-green or green algae because of their high silicate content and is not directly related to total plankton.

Concentrations of chlorophyll *a* (an indication of the relative amount of green algae varied from 0.3 µg/L to 4.4 µg/L (Table 4). Chlorophyll *a* levels in Smoothstone Lake were generally lowest in spring and increased somewhat as the growing season progressed. Seasonal means at the two sampling stations were similar, at 2.3 µg/L at station A and 2.4 µg/L at station B (surface samples), with one exception (Station A, June 24), only minor differences occurred between surface and bottom samples. This is consistent with the observations that the lake is generally shallow and lacks thermal stratification. These values are typical of lakes located in a forest watershed (Liaw 1982).

4.3 BOTTOM FAUNA

Seventy-eight Ekman grab samples of lake sediments were taken in Smoothstone Lake in 1988 (Fig. 6). Numbers and weights of

Table 4. Levels of chlorophyll *a* (µg/L) in Smoothstone Lake, 1988. Values are corrected for phaeo-pigment.

Date	Station A		Station B	
	surface	bottom	surface	bottom
May 25	0.334	1.782	1.403	1.959
June 10	1.069	1.967	1.871	3.159
June 24	2.205	9.088*	2.673	1.553
July 9	3.609	2.740	3.675	3.074
July 22	1.537	2.072	2.406	2.072
August 4	2.673	1.403	2.138	2.673
August 17	4.410	1.300	2.673	0.945
Mean	2.262	2.907**	2.406	2.205

* Suspect value too high due to sampling or analytical error.
** Mean includes suspect value - probably too high.

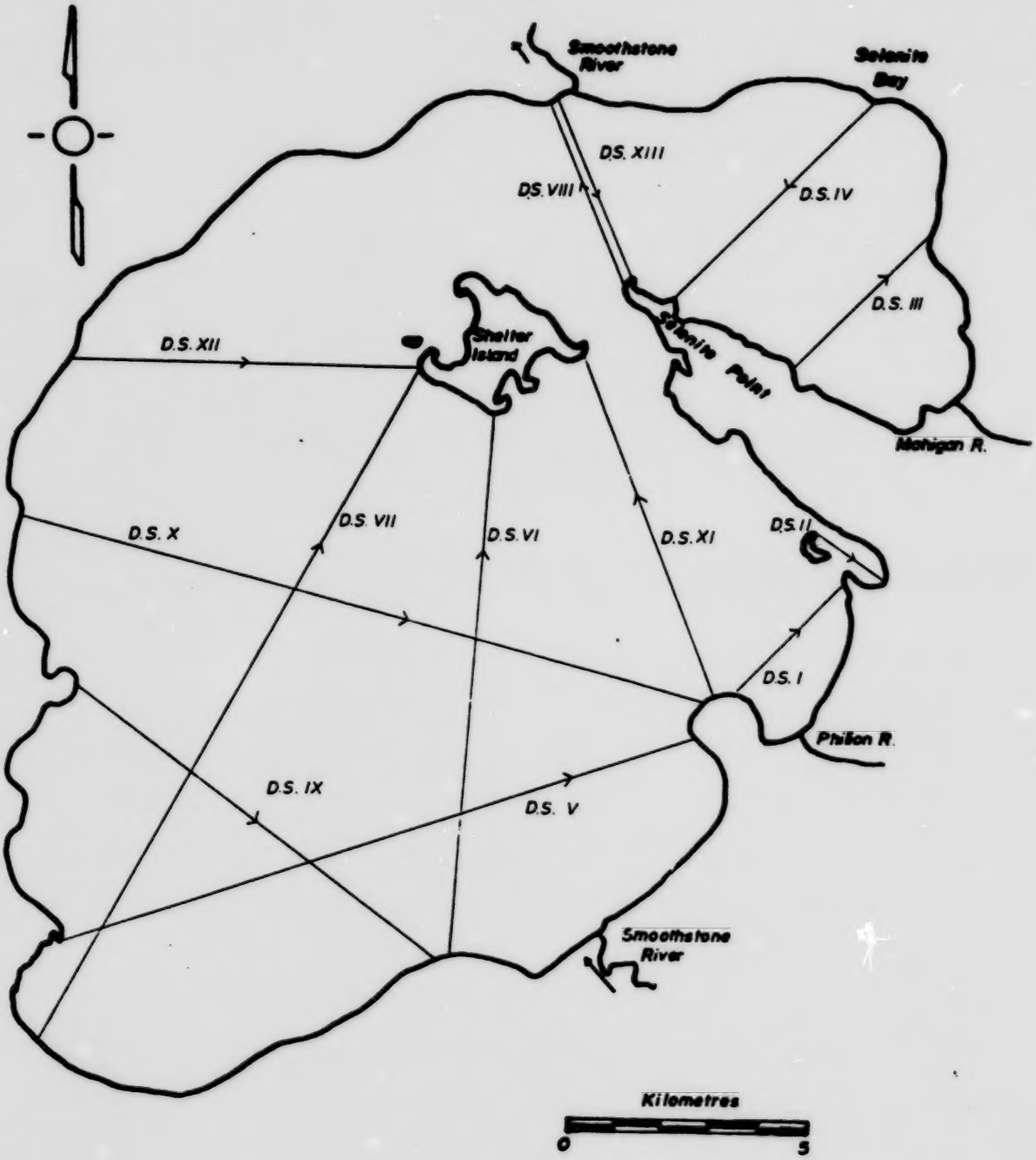

Fig. 6 Locations of dredging series taken in Smoothstone Lake, 1988.

organisms collected are given in Appendix 4. The bottom fauna were dominated by Chironomidae (midge larvae), which comprised almost 65% of the total number of organisms collected (Table 5). Oligochaeta (sludge worms) were next in abundance (20.9%), followed by amphipods (freshwater shrimp: 7.3%) and sphaeriids (fingernail clams: 5.8%). Hirudinea (leeches), Coleoptera (beetles), Ephemeroptera (mayfly nymphs), Trichoptera (caddisfly larvae), Ceratopogonidae (biting midges), gastropods (snails) and unidentified benthos each comprised <1% of the total number of organisms collected. Highest numbers of organisms/m^2 were captured in the 0 - 5 m and 10 - 15 m depth zones; lowest numbers were collected in depths >25 m. The low numbers of benthic organisms found in the 5 - 10 m depth may possibly be the result of predation by whitefish and suckers.

Twenty-seven dredge samples were collected in 1956. Chironomids were also the dominant organism collected in terms of number (Scott 1956), followed by sphaeriids, oligochaetes and amphipods (Table 6).

Total number of organisms captured in 1988 was 810/m^2, which is about five times more than the 158 organisms/m^2 collected in 1956 (Table 6). Standing biomass of benthic organisms in Smoothstone Lake was 8.0 kg/ha in 1988, which is substantially greater than the 2.2 kg/ha determined in 1956 (Scott 1956).

Table 5. Depth distribution of benthic organisms (per m^2), Smoothstone Lake, 1988.

Benthic organism:	Depth range (m) 0-5	5-10	10-15	15-20	20-25	25-30	All Depths*	%
Oligochaeta	220	105	201	164	160	70	169	20.9
Hirudinea	2	0	4	1	0	0	2	0.2
Amphipoda	270	6	30	11	5	0	59	7.3
Coleoptera	0	0	1	0	0	0	<1	<0.1
Ephemeroptera	9	1	4	3	0	0	4	0.5
Trichoptera	10	0	1	0	0	0	2	0.2
Ceratopogonidae	4	3	1	0	0	0	2	0.2
Chironomidae	577	357	804	357	415	130	516	63.7
Gastropoda	24	1	0	0	0	0	4	0.5
Sphaeriidae	142	17	61	12	3	0	47	5.8
Unidentified	1	7	4	8	3	20	5	0.6
Total no/m^2	1259	497	1111	556	586	220	810	
No. of dredges	20	19	14	15	8	2	78	
% water area	17.5	20.2	26.1	21.6	13.3	0.8		
Dry wt, mg/m^2	540	329	1031	1028	1105	610	804	

*Values weighted for percentage depth strata

Table 6. Comparison of bottom fauna in Smoothstone Lake, 1956 and 1988. All values are weighted for percentage depth strata.

	Average no. of organisms/m^2		%	
	1956	1988	1956	1988
No. of samples	27	78		
Amphipoda	5	59	3.2	7.3
Chironomidae	113	516	71.5	63.7
Gastropoda	0	4	0	0.5
Sphaeriidae	24	47	15.2	5.8
Oligochaeta	13	169	8.2	20.9
Other	3	1	1.9	1.7
Total number	158	810	100.0	100.0
Average dry wt, kg/ha	2.2	8.0		

4.4 FISH

4.4.1 Species Composition and Relative Abundance

Samples of the fish population in Smoothstone Lake were obtained by seining and gillnetting (Fig. 7 and 8). Seventeen species of fish were collected during the study, 8 in 26 netsets and the remainder by seining as listed in Table 7. Only 8 species of fish were captured in 1956 (Scott 1956), and 7 species in the test nets set in 1976 (Walton 1977) although in the earlier studies sampling effort was considerably lower (1956-5, 1976-6). The absence of minnows and other small fish species in 1956 is probably the result of inadequate sampling since only two seine hauls were pulled. No seine hauls were pulled in 1976.

White sucker was the dominant fish captured in the gillnets in 1988, comprising 33.7% by number and 38.8% by weight of the total catch (Appendix 5). Perch ranked second in numbers, making up 21.1% of the fish caught but just 2.6% of the catch by weight. Longnose sucker ranked third in terms of numbers, comprising 17.1% of fish caught and 24.2% of the weight. Pike comprised 3.4% of the total number and 12.9% of the weight of fish caught in the gillnets. Only 1 walleye was caught in the gillnets in 1988, making up <0.1% of the gillnet catch both in number and weight. Other species caught in the gillnets consisted of burbot (0.5%), cisco (9.8%) and whitefish (14.4%).

Fig. 7 Locations of seine hauls in Smoothstone Lake, 1988.

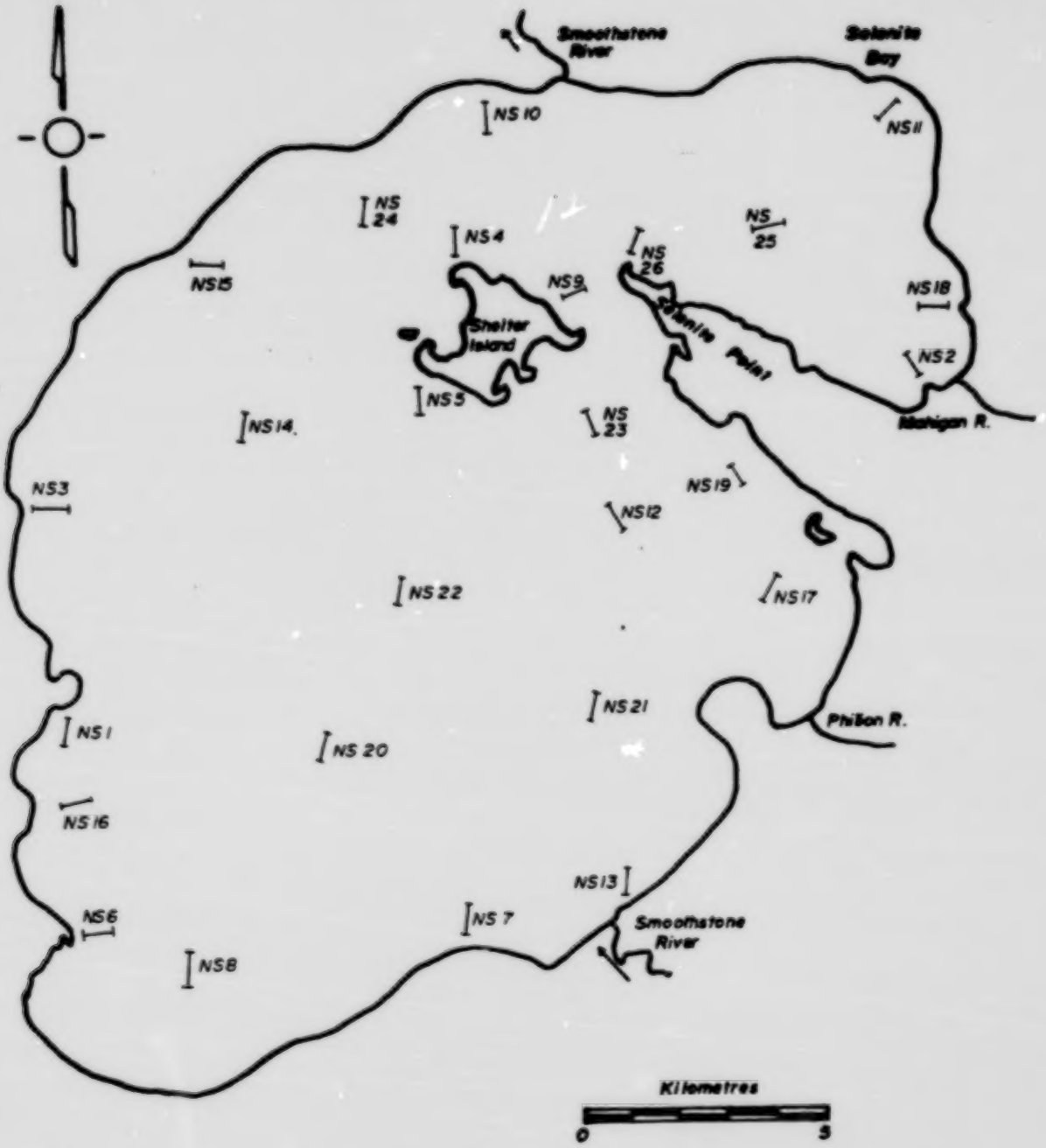

Fig. 8 Locations of gillnet sets in Smoothstone Lake, 1988.

Table 7. Fish species collected during the surveys in Smoothstone Lake in 1956 and 1988.

Common name	Scientific name	Collected in 1956	Collected in 1988
Lake whitefish	*Coregonus clupeaformis*	+	+
Cisco	*Coregonus artedii*	+	+
Northern pike	*Esox lucius*	+	+
Fathead minnow	*Pimephales promelas*		+
Longnose dace	*Rhinichthys cataractae*		+
Emerald shiner	*Notropis atherinoides*		+
Spottail shiner	*Notropis hudsonius*		+
Longnose sucker	*Catostomus catostomus*	+	+
White sucker	*Catostomus commersoni*	+	+
Trout-perch	*Percopsis omiscomaycus*		+
Burbot	*Lota lota*	+	+
Brook stickleback	*Culaea inconstans*		+
Ninespine stickleback	*Pungitius pungitius*		+
Yellow perch	*Perca flavescens*	+	+
Walleye	*Stizostedion vitreum*	+	+
Logperch	*Percina caprodes*		+
Iowa darter	*Etheostoma exile*		+

In 1956, whitefish was the dominant species caught in the gillnets, comprising 30.6% by number and 29.5% by weight of fish collected (Table 8). Perch and white sucker ranked second and third in terms of relative abundance. Pike and walleye each made up 2.3% of the total number of fish captured in 1956.

In 1976, the most numerous species caught in the gillnets was perch (35.0%) followed by white sucker (26.9%) and cisco (23.9%). Whitefish accounted for only 3.3% by number of the gillnet catch. No walleye were caught in 1976 nets.

Almost 85% of the fish caught by gillnetting in 1988 were taken in the three smallest mesh sizes ranging from 3.8 - 7.6 cm (Appendix 6). Only 3.3% of the fish were taken in the two largest mesh sizes of gillnet. In terms of weight of fish, the 7.6 cm mesh gillnet was most effective.

Gillnets set in Smoothstone Lake in 1988 caught an average of 163 fish per net set, which is similar to the 173.5 fish caught per net set in 1976, but almost double the 85 fish per net set caught in 1956 (Table 8). Only 5 standard gangs were set in 1956, and 4 sets were made in 1976, so results may not be representative.

Thirteen species of fish were caught by seining in Smoothstone Lake in 1988 (Table 9). Yellow perch were most abundant. They were collected in 90% of the seine hauls and made up >30% of the total number of fish collected. Spottail shiners, ninespine stickleback, emerald shiners and fathead minnows were also common in the

Table 8. Comparison of average catch of fish per standard gang gillnet set in Smoothstone Lake, 1956*. (5 sets), 1976** (4 sets) and 1988 (26 sets).

	Number			Percent			Weight, kg			Percent		
	1956	1976	1988	1956	1976	1988	1956	1976	1988	1956	1976	1988
Perch	17.4	60.8	34.4	20.5	35.0	21.1	1.4	3.6	1.6	4.0	10.7	2.6
Pike	2.0	1.9	5.5	2.3	1.1	3.4	4.9	2.6	8.0	13.8	7.7	12.9
Walleye	2.0	0.0	<0.1	2.3	0.0	<0.1	1.8	0.0	<0.1	5.0	0.0	<0.1
Whitefish	26.0	5.7	23.5	30.6	3.3	14.4	10.5	1.7	11.0	29.5	5.0	17.7
Burbot	0.4	0.7	0.8	0.5	0.4	0.5	1.1	0.7	1.6	3.0	2.1	2.6
Cisco	8.4	41.4	16.0	9.9	23.9	9.8	0.4	2.1	0.7	1.2	6.1	1.2
White sucker	17.0	46.7	54.8	20.0	26.9	33.7	9.8	11.9	24.1	27.6	35.1	38.8
Longnose sucker	11.8	16.3	27.8	13.9	9.4	17.1	5.6	11.3	15.0	15.9	33.3	24.2
All species	85.0	173.5	162.9	100.0	100.0	100.0	35.5	33.9	62.1	100.0	100.0	100.0

* Scott 1956
** Walton 1977

Table 9. Seine net catches in Smoothstone Lake, 1988. See Fig. 7 for locations.

	Seine haul number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total	Per Cent
Number of:																					
Northern pike	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	<0.1
Fathead minnow	8	1	0	21	2	68	0	0	3	1	6	0	2	0	0	10	10	9	18	159	7.8
Longnose dace	0	0	9	7	0	0	0	0	12	0	3	0	2	0	0	0	0	1	2	36	1.8
Emerald shiner	13	17	63	0	0	0	0	0	9	1	1	0	3	0	0	0	13	12	58	190	9.3
Spottail shiner	150	26	25	3	0	1	1	0	8	2	62	37	27	9	2	5	15	3	24	400	19.7
Longnose sucker	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0.1
White sucker	0	0	0	1	0	0	4	0	0	3	15	0	0	0	0	0	6	0	16	45	2.2
Trout-perch	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	5	0.3
Brook stickleback	0	0	0	0	14	1	0	0	0	8	0	0	0	0	0	6	2	13	0	44	2.2
Ninespine stickleback	0	0	0	1	10	0	1	41	1	104	2	0	1	6	0	2	6	3	23	201	9.9
Yellow perch	0	8	2	10	1	0	3	11	21	24	7	6	288	76	76	59	41	2	2	637	1.3
Logperch	0	11	2	3	3	0	2	0	1	0	4	1	2	8	1	0	0	0	0	38	1.8
Iowa darter	0	0	0	2	4	0	0	0	0	14	0	0	0	1	1	0	0	11	0	33	1.6
Unidentified*	0	0	58	0	1	118	0	0	0	0	0	0	5	0	1	1	0	1	58	243	11.9

* Sucker fry

seine hauls. Only one juvenile pike was caught in the seine hauls, and no juvenile walleye or whitefish were collected.

4.4.2 Characteristics of Major Species

4.4.2.1 Northern Pike

The pike population appears to have doubled from 2.0/net set in 1956 to 5.5/net set in 1988. Pike made up 3.4% of the gillnet catch by number and about 12.9% by weight (Appendix 5). Relative numbers have not changed substantially in Smoothstone Lake in the last three decades since pike comprised 2.3% of the gillnet catch in 1956 and 1.1% in 1976 (Table 8). Only 1 juvenile pike was caught by seining in 1988 and none were collected in 1956 or 1976.

Length frequency distribution of pike caught in the various sizes of gillnet used in Smoothstone Lake in 1988 is shown in Fig. 9. The 5.1 and 7.6 cm meshes were most effective as almost 75% of the pike were captured in these meshes. Only 1 pike was caught in the two largest mesh sizes.

The length frequency distribution of the pike population in Smoothstone Lake is shown in Fig. 10. The majority of the 142 pike caught during the 1988 survey were between 51 and 61 cm in fork length. The length frequency distribution of the 10 pike caught in 1956, and 12 pike caught in 1976, are also illustrated but do not show a definite pattern because of the small sample size. Average fork length of pike

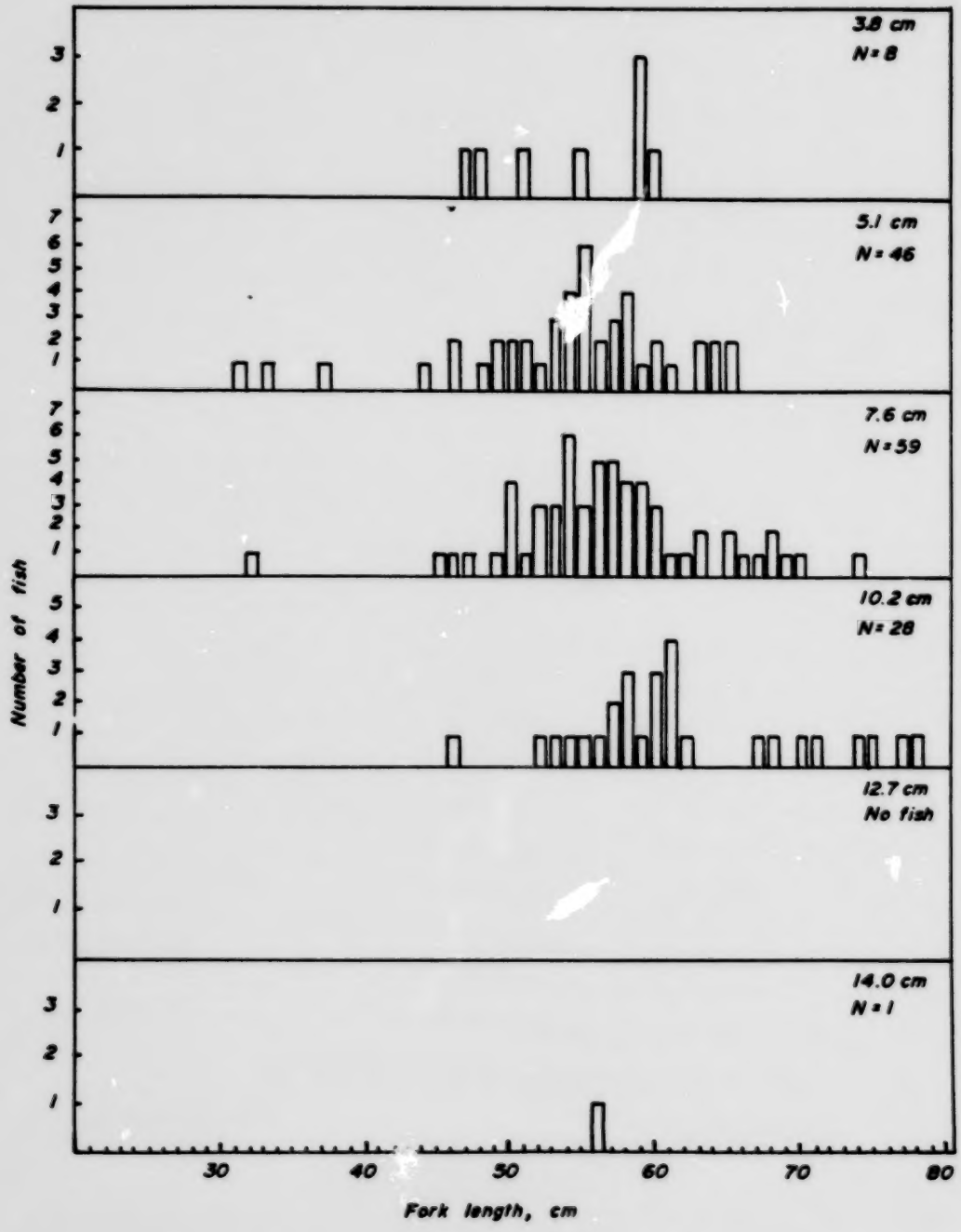

Fig. 9 Length distribution of pike caught in the various mesh sizes of gillnet used in Smoothstone Lake, 1988. N = sample size.

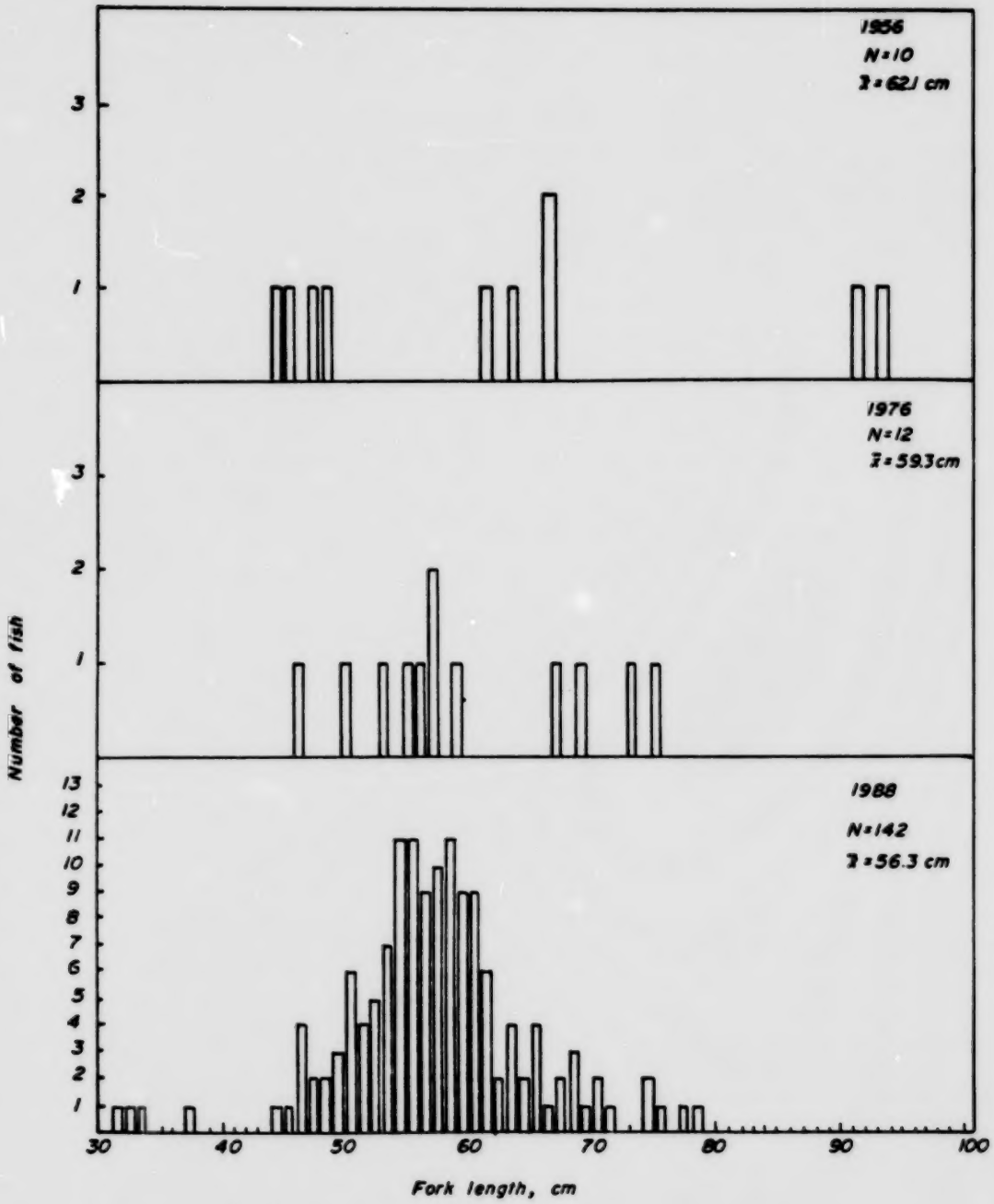

Fig. 10 Length frequency distribution of pike captured in gillnets in Smoothstone Lake in 1956, 1976 and 1988. N = sample size ; X̄ = mean fork length.

caught in gillnets was 56.3 cm in 1988, 59.3 cm in 1976 and 62.1 cm in 1956.

The length-weight relationships of pike captured in 1956, 1976 and 1988 are shown in Fig. 11. The length-weight curves are illustrated by the equations:

1956	$W=0.005L^{3.130}$
1976	$W=0.007L^{3.039}$
1988	$W=0.013L^{2.883}$

where W is weight in grams and L is fork length in centimetres. The average weight of pike captured in 1988 was 1481 g. The largest pike caught in Smoothstone Lake in 1988 was 77.5 cm long and weighed 3700 g.

A condition coefficient, K, can be calculated to get an indication of the relative robustness, or "well-being" of a fish population. Calculation of the coefficient was based on the formula, $K=W/L^3$ (Carlander 1969) where W is weight in kilograms and L is fork length in centimetres. Condition of male and female pike captured in the gillnets in 1988 was similar:

Female:	K=0.77
Male:	K=0.80

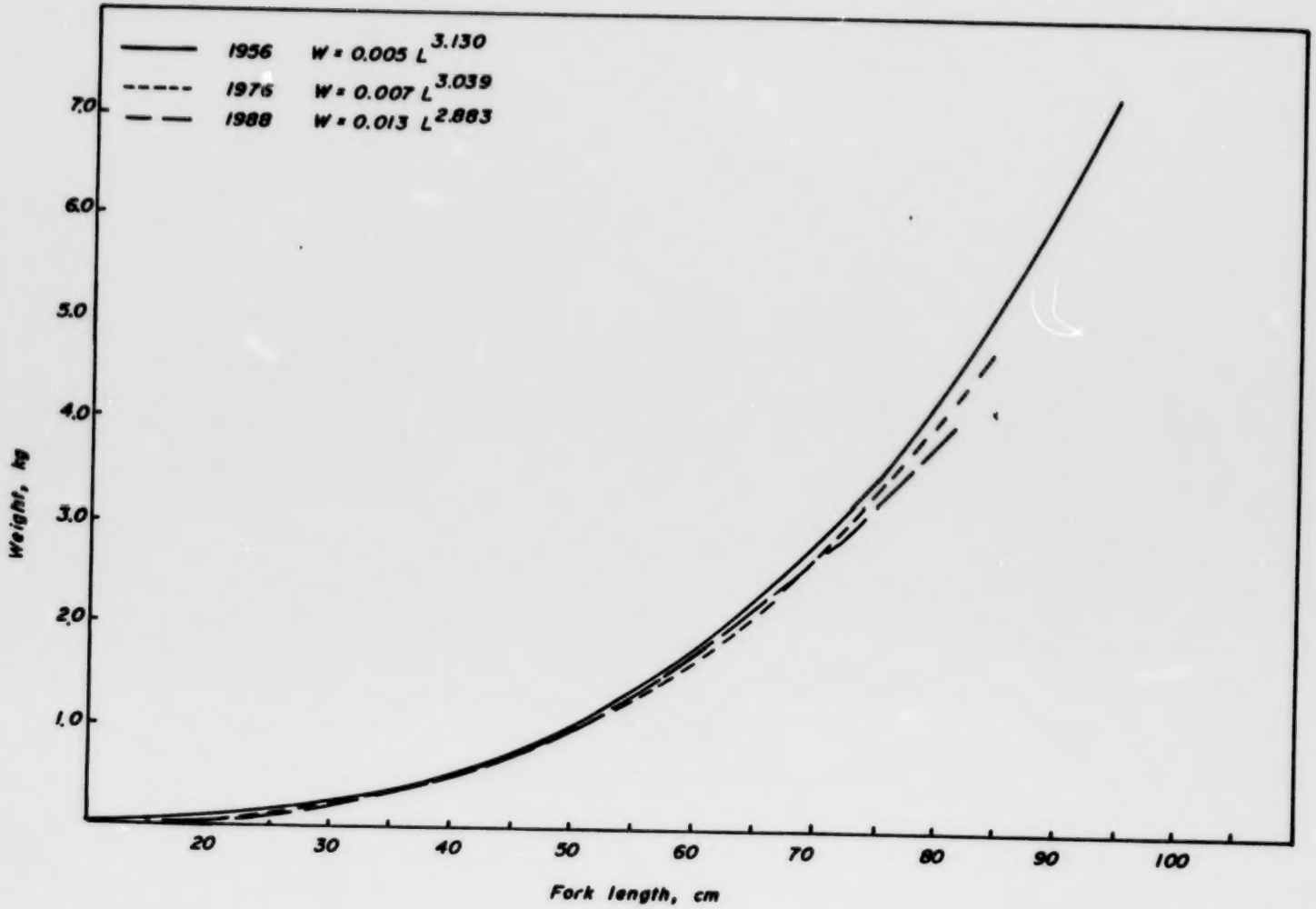

Fig. 11 Length - weight relationship of pike captured in gillnets in Smoothstone Lake in 1956, 1976 and 1988.

These values are similar to the condition factor determined for pike captured in 1956 (0.81) and 1976 (0.77), without considering the sexes separately.

Scales and cleithra were obtained from 120 pike for ageing purposes, based on a sample of 10 fish for each cm of length, where possible. A comparison of results (Table 10) indicates that the two media are similar for the pike captured in Smoothstone Lake. Age composition and growth of pike, based on scale age, are shown in Fig. 12. Ages of pike caught by gillnetting ranged from 1 to 8 yr, with the majority in the 3 yr age class.

Information collected was adequate to estimate size at maturity for pike in Smoothstone Lake. All of the pike >46 cm long that were examined were mature. At this length, they would be approximately 2 yr of age.

Pike were not observed spawning in Smoothstone Lake in 1988. However, pike captured in the gillnets set on May 30 were ripe or spent, indicating that spawning was occurring. Areas suitable for pike reproduction are not common in Smoothstone Lake. Some marshy, weedy areas occur along the southwestern shore of the lake, and around Shelter Island. Muskeg is also found along the northeastern shore of Selenite Bay. Pike are known to swim up the inflowing Smoothstone River as far as Clarke Lake in the spring to spawn. Access to Little Clarke lake is blocked by an old water level control structure. Although other tributaries suitable for pike spawning occur in the area, the streams

Table 10. Comparison of scale ages and mean cleithrum ages of northern pike from Smoothstone Lake, 1988.

Scale age, yr	Mean cleithrum age, yr	Standard deviation	No. of fish
1	1.0	-	1
2	2.0	0.0	11
3	3.0	0.2	38
4	4.0	0.3	27
5	4.9	0.7	30
6	5.9	0.5	11
7	7.0	-	2

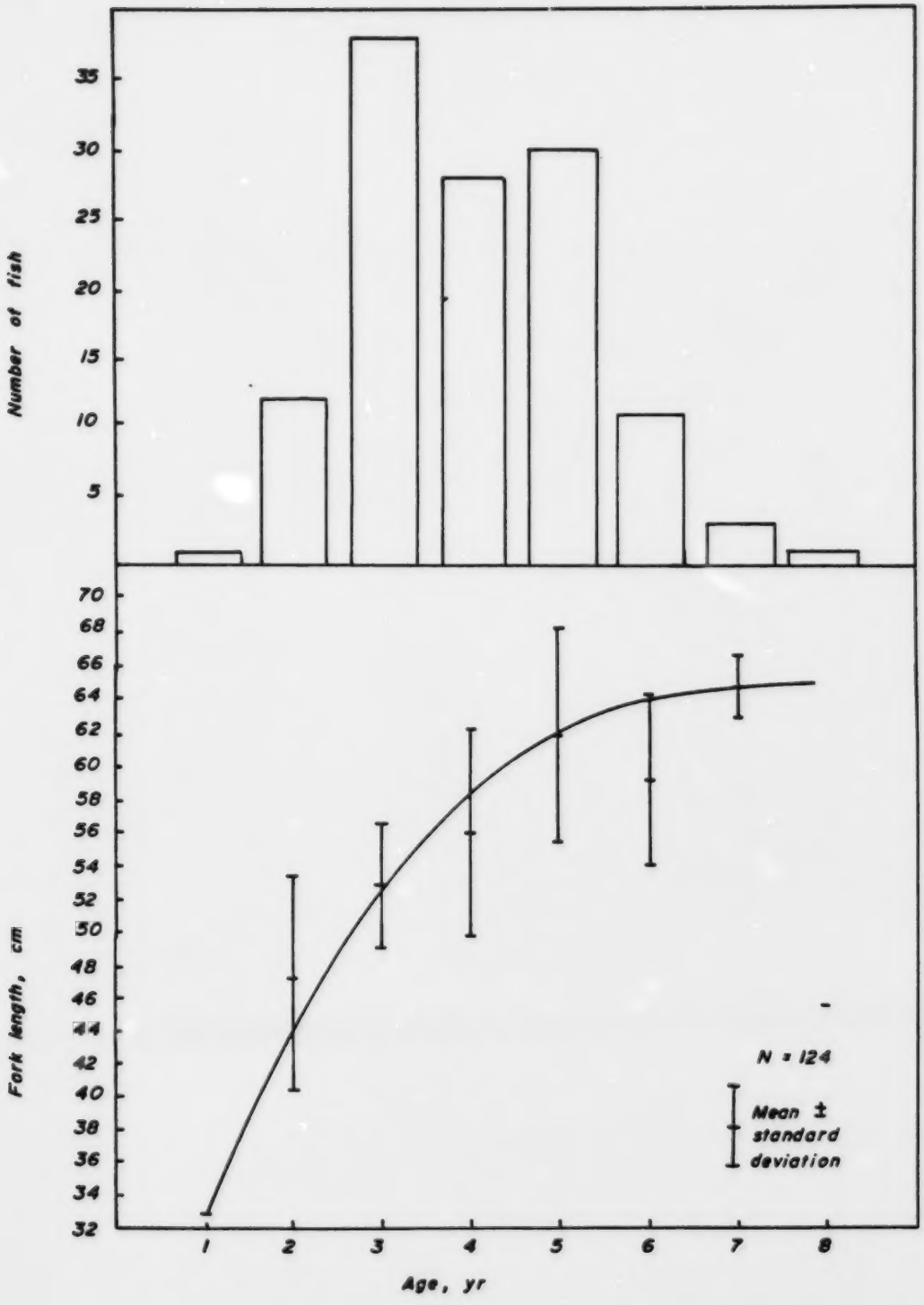

Fig. 12 Age composition and growth of pike captured in gillnets in Smoothstone Lake, 1988. Ages were determined from scales. N= number of fish.

become blocked by beaver activity every summer and restrict access to spawning pike during breakup the following spring. Success of the pike population in Smoothstone Lake has probably been limited by lack of suitable spawning grounds and subsequent poor reproduction.

Analysis of 142 adult pike captured in the gillnets (Appendix 7) indicates that pike in Smoothstone Lake rely mainly on fish as a food source. Over 90% of the food remains in the pike stomachs consisted of fish, including stickleback (21.4%), cisco (11.9%), perch (10.3%), trout-perch (10.3%) and white sucker (9.5%). Approximately 60% of the pike stomachs examined were empty. With the high proportions of perch and ciscoes in the lake, food supplies for pike appear to be abundant.

4.4.2.2 Lake Whitefish

Whitefish comprised 14.4% by number and 17.7% by weight (Appendix 5) of fish caught by gillnetting in Smoothstone Lake in 1988. Whitefish populations appear to have fluctuated over the last three decades: an average of 23.5 fish per net set was caught in 26 netsets in 1988 whereas, in 1956, 26.0 fish per set was taken in 5 sets and in 1976, 5.7 fish were caught in 4 sets (Table 8). Relative abundance of whitefish in Smoothstone Lake has decreased since 1956 when this species comprised 30.6% by number and 29.5% by weight of fish caught in the gillnets. In 1976, whitefish made up 3.3% by number and 5.0% by weight of the gillnet catch.

Length frequency distribution of whitefish caught in the various mesh sizes of gillnet is shown in Fig. 13. The 7.6 cm mesh was most effective in catching whitefish, as over 40% of the fish were taken in this mesh. The two largest mesh sizes (12.7 and 14.0 cm) were least effective in catching whitefish, selectively holding only the larger fish.

Length frequency distributions of whitefish captured in gillnets in 1956, 1976 and 1988 are illustrated in Fig. 14. In 1956, the majority of whitefish were 30-37 cm in fork length. In 1988, most fish were 34-40 cm. Lengths of most whitefish captured in gillnets in 1976 were between 29-37 cm. Average fork lengths of whitefish caught in 1956, 1976 and 1988 were similar, at 31.0 cm, 30.8 cm and 32.1 cm, respectively.

The length-weight relationships for whitefish caught in gillnets in 1956, 1976 and 1988 are illustrated by the equations:

$$1956: W=0.018L^{2.882}$$

$$1976\ \ W=0.016L^{2.900}$$

$$1988: W=0.006L^{3.197}$$

The curves generated by the relationships are shown in Fig. 15. The divergence of the curves among the larger fish is caused by small sample size and state of gonad development. Average weight of whitefish caught

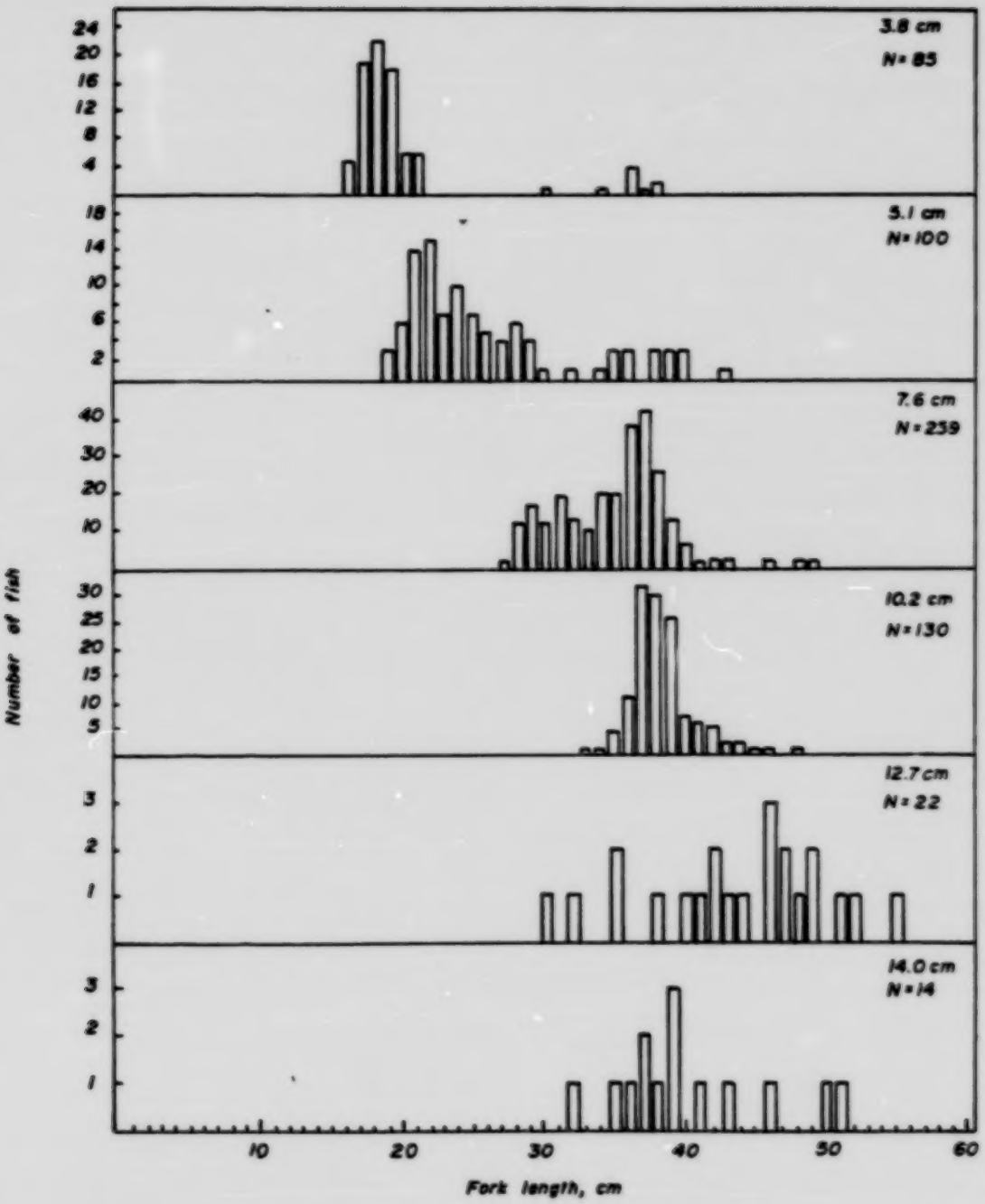

Fig. 13 Length distribution of whitefish caught in the various mesh sizes of gillnet used in Smoothstone Lake, 1988. N = sample size.

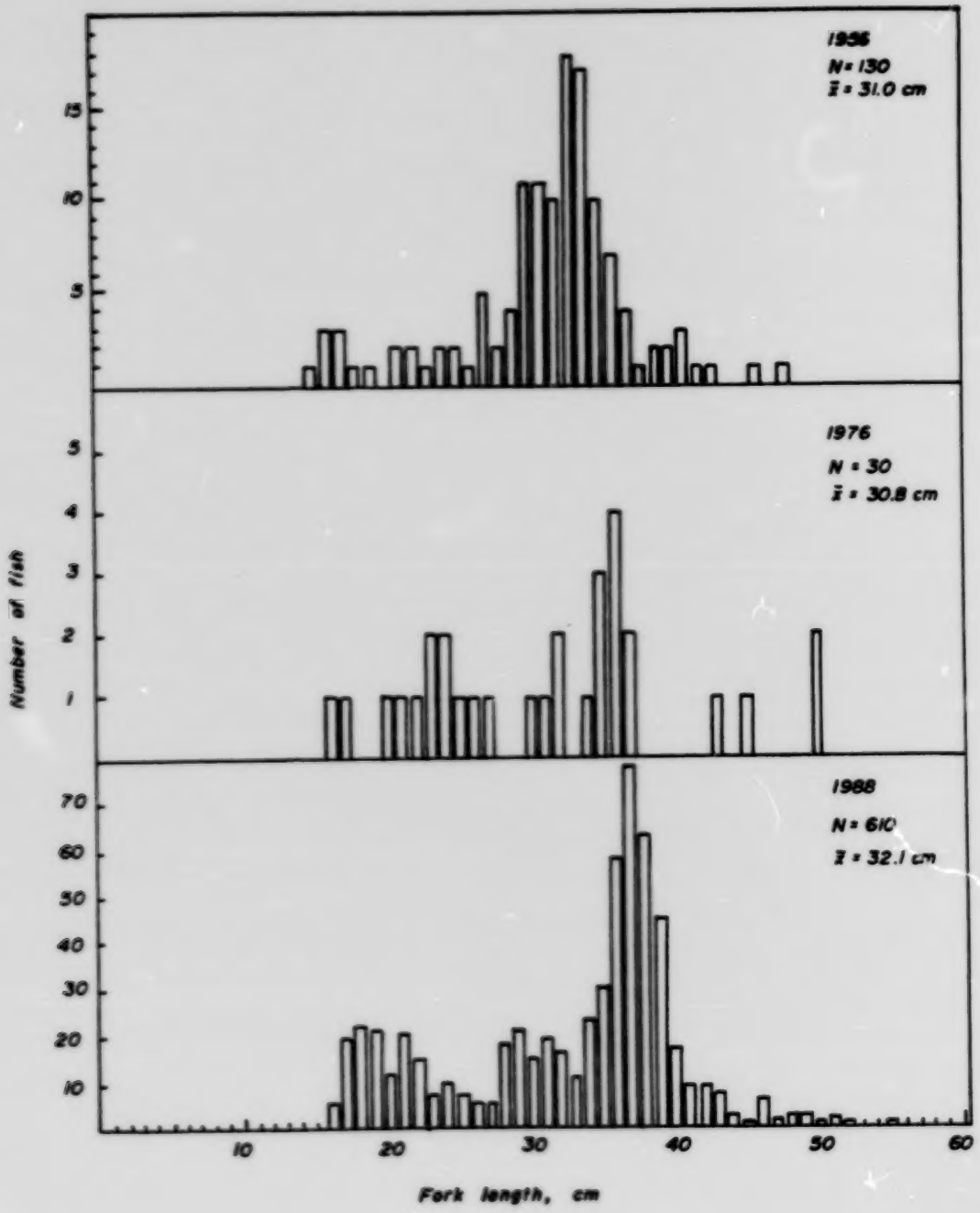

Fig. 14 Length frequency distribution of whitefish captured in gillnets in Smoothstone Lake in 1956, 1976 and 1988. N = sample size; $\bar{x}$ = mean fork length.

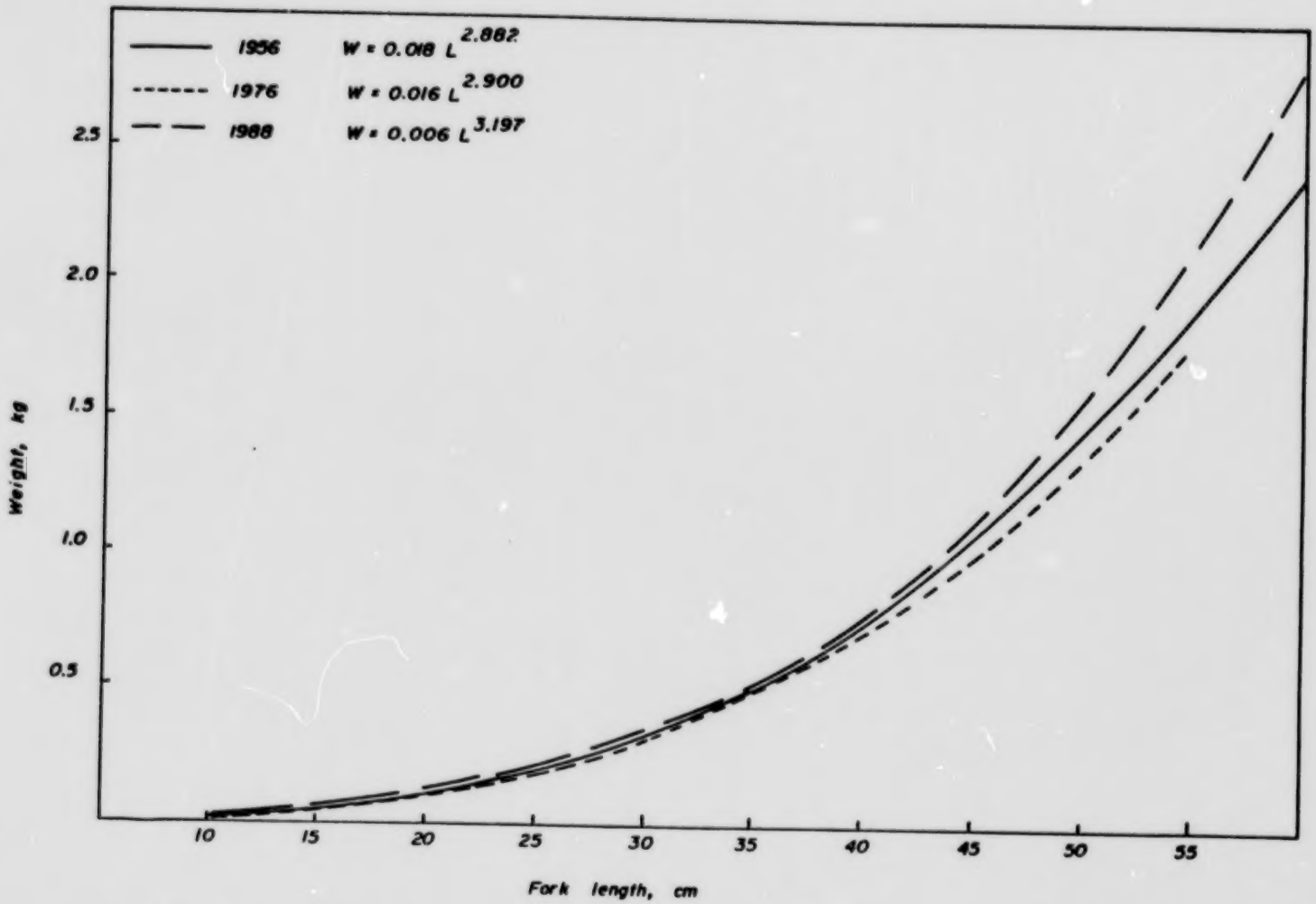

Fig. 15 Length-weight relationship of whitefish captured in gillnets in Smoothstone Lake in 1956, 1976 and 1988.

in the gillnets in 1988 was 469 g. The largest whitefish caught in 1988 weighed 2600 g.

Condition factors for male and female whitefish taken in the gillnets in Smoothstone Lake in 1988 were similar:

Female: K=1.17

Male: K=1.19

Average condition of whitefish captured in 1956 was substantially greater, at 1.44 (both sexes combined), indicating that whitefish caught in the earlier study were more robust. Condition of whitefish captured in nets in 1976 was 1.15, similar to the condition of fish caught in the present study.

Scales and otoliths were obtained from 146 whitefish for ageing purposes, based on a sample of 10 fish from each cm of length where possible. A comparison of results indicates that the two media are similar for fish up to 5 yr old (Table 11). After 5 yr, ages determined from otoliths are consistently higher. Age composition and growth of whitefish, based on scale age for fish up to 5 yr and otolith age for fish older than 5 yr, are depicted in Fig. 16. Ages of whitefish caught by gillnetting ranged from 1 to 30 yr, with the majority falling into the 5 yr class.

Size at maturity is defined as the size at which 50% of the fish have reached sexual maturity. Calculation of size at maturity for whitefish caught in Smoothstone Lake in 1988 is given in Appendix 8,

Table 11. Comparison of scale ages and mean otolith ages of whitefish from Smoothstone Lake, 1988.

Scale age, yr	Mean otolith age, yr	Standard deviation	No. of fish
1	1.1	0.3	9
2	2.0	0.6	6
3	3.3	0.5	6
4	4.8	0.7	14
5	6.1	2.3	34
6	7.8	3.1	37
7	11.9	2.8	28
8	12.0	2.6	4
9	15.0	-	2
10	12.3	0.5	3
11	11.0	-	1
12	20.5	-	2

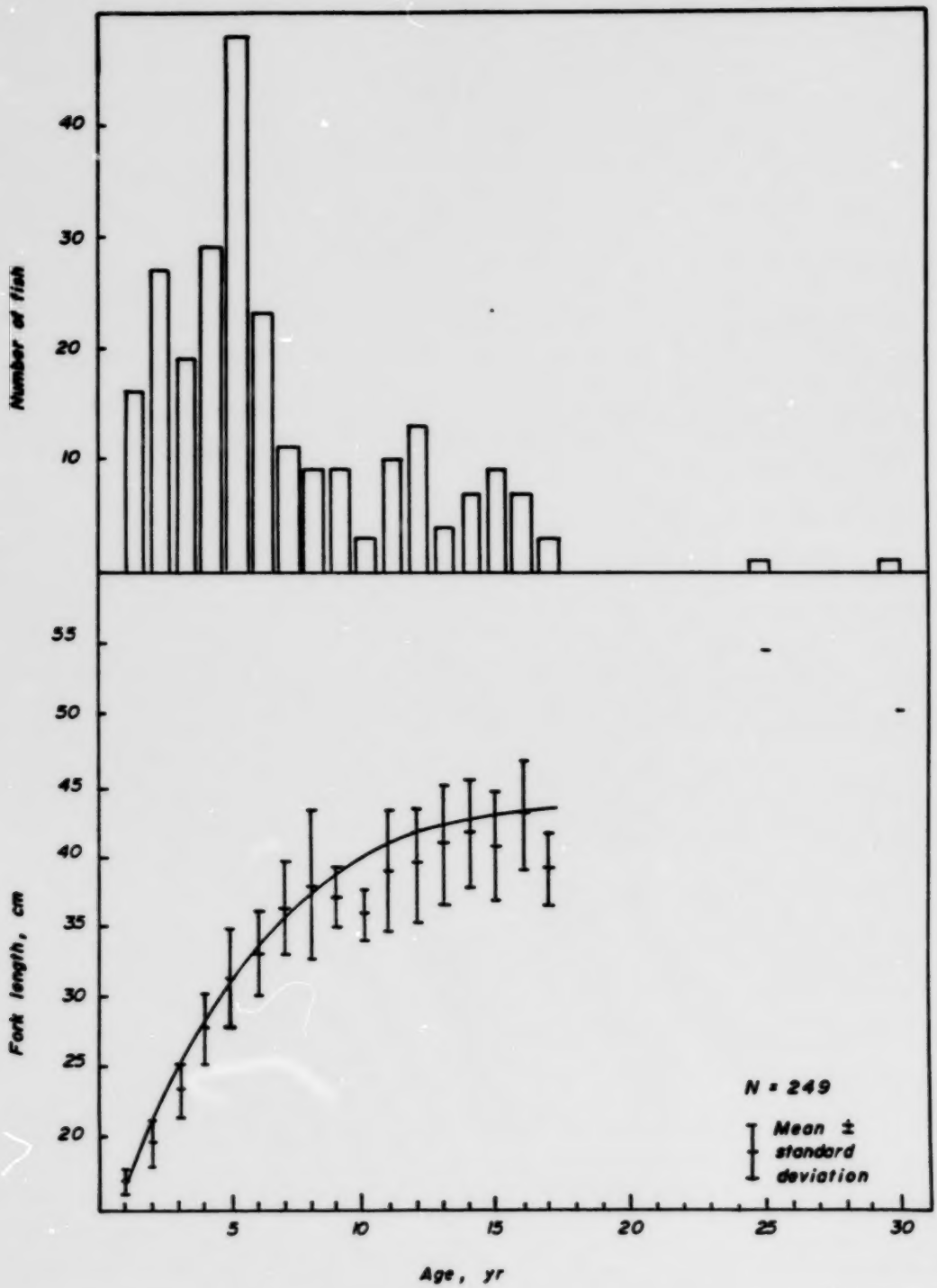

Fig. 16 Age composition and growth of whitefish captured in gillnets in Smoothstone Lake, 1988. Ages were determined from scales for fish up to 5 yr and from otoliths for fish older than 5 yr. N = number of fish.

following the equation of Ni and Sandeman (1984). Using this method suggests that female whitefish mature at 28.5 cm and males at 26.5 cm, when they are 4-5 yr old.

A total of 407 whitefish stomachs were examined for food contents. Results are given in Appendix 9. Insects made up almost 70% of the organisms found. Chironomids (midge larvae) were the dominant food item eaten by whitefish, making up almost 65% of the composition by volume. Other items consumed included sphaeriids (fingernail clams), amphipods (freshwater shrimp), plant material and fish remains. Less than 40% of the whitefish stomachs were empty.

Infestation of whitefish in Smoothstone Lake with the tapeworm *Triaenophorus crassus* was determined by examining 73 whitefish for cysts. Number of cysts ranged from 0 - 5, with a mean of 1 cyst per fish (Table 12). Thirty-four percent of the whitefish examined were infested. The rate of infestation was 43 cysts per 100 lb of whitefish which would rank the lake as continental in marketing quality. Smoothstone lake is presently recognized as a cutter lake (>80 cysts/100 lb).

4.4.2.3 Yellow Perch

Yellow perch ranked second in abundance in terms of numbers of fish captured in Smoothstone Lake, comprising 21.1% of the gillnet catch (Appendix 5). Actual numbers of perch caught per net set have increased in the last three decades: in 1956, an average of 17.4 perch

Table 12. Infestation of whitefish by tapeworm (*Triaenophorus crassus*) in Smoothstone Lake, 1988.

Date	No. of Fish	Total wt, kg	No. of cysts range	No. of cysts mean	No. Cysts	% Infested	Total ROI* /100 lb
July 23	11	6.6	1-4	1	7	36.4	48
July 24	10	6.1	0-5	1	14	78.6	104
July 25	14	9.0	0-3	<1	5	21.4	25
July 25	14	8.7	0-5	1	9	21.4	47
July 25	14	9.1	0-2	<1	6	14.3	30
July 25	10	7.2	0-1	<1	3	30.0	19
Total	73	46.7	0-5	1	44	34.0	43

* Rate of infestation

per net set was caught whereas in 1976, 60.8 perch per set were taken and in 1988, 34.4 perch per set were taken (Table 8). Yellow perch were the most abundant species captured in the seine nets in 1988, and were collected in all but two seine hauls.

Length distribution of 191 perch caught in the various mesh sizes of gillnet set in Smoothstone Lake in 1988 is shown in Fig. 17. The 3.8 cm mesh gillnet was most effective, capturing 77% of the perch.

Length frequency distribution of 191 perch caught in 1988 and 87 perch captured in 1956 is shown in Fig. 18. The majority of perch caught in 1988 were between 14 cm and 17 cm in fork length, whereas in 1956, most were between 15 cm and 23 cm. Average fork length of perch caught in 1988 was 15.3 cm, slightly smaller that the average length (17.6 cm) of perch taken in 1956. No statistics are available for the perch caught in 1976.

The length-weight relationships for perch taken in 1956 and in 1988 are illustrated by the equations:

1956: $W=0.037L^{2.014}$

1988: $W=0.015L^{2.816}$

Perch captured in 1956 were heavier per unit length than fish caught in 1988, as illustrated by the length-weight curves (Fig 19). The length-weight relationships are highly significant at the 95% confidence level.

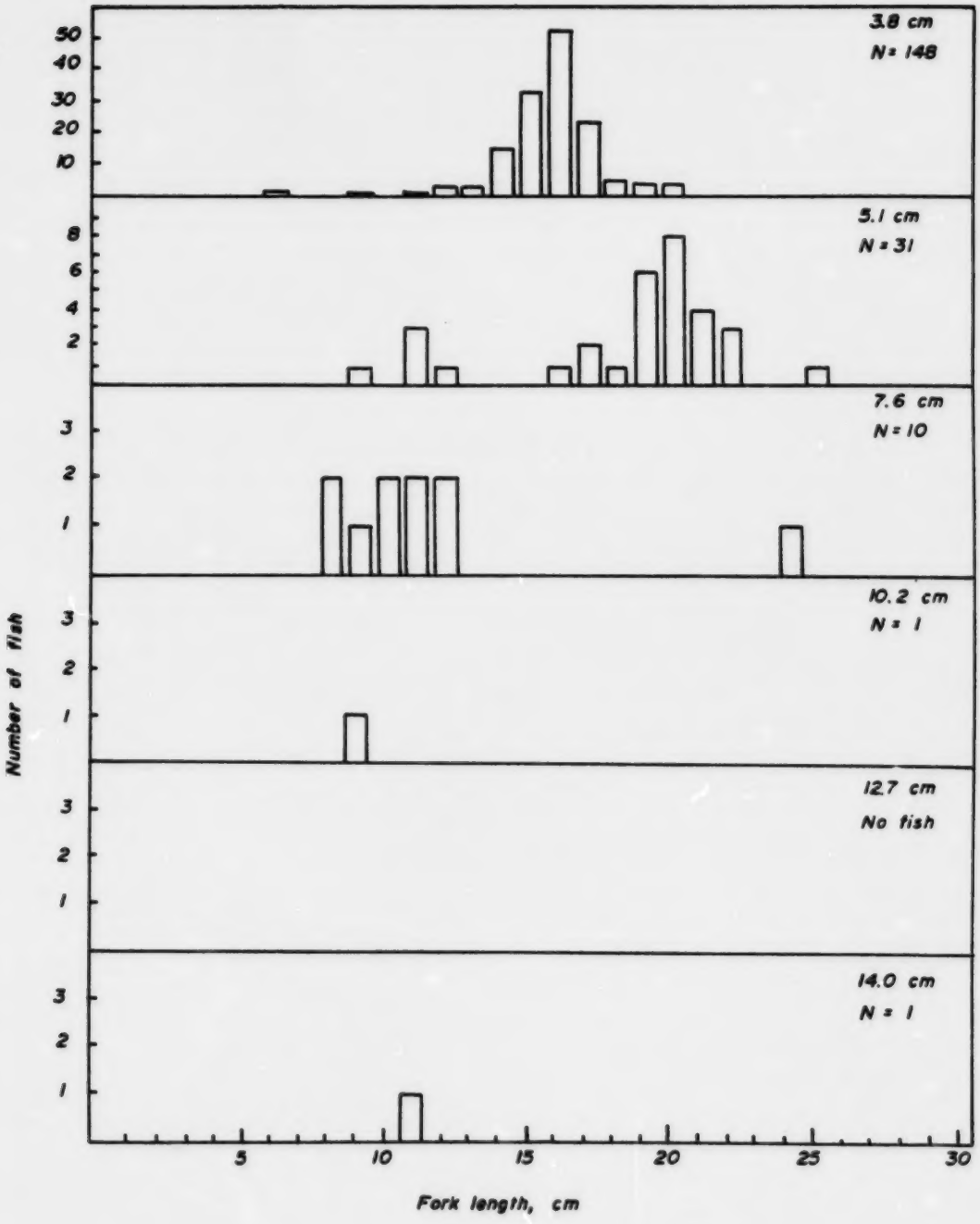

Fig. 17 Length distribution of yellow perch caught in the various mesh sizes of gillnet used in Smoothstone Lake, 1988. N = sample size.

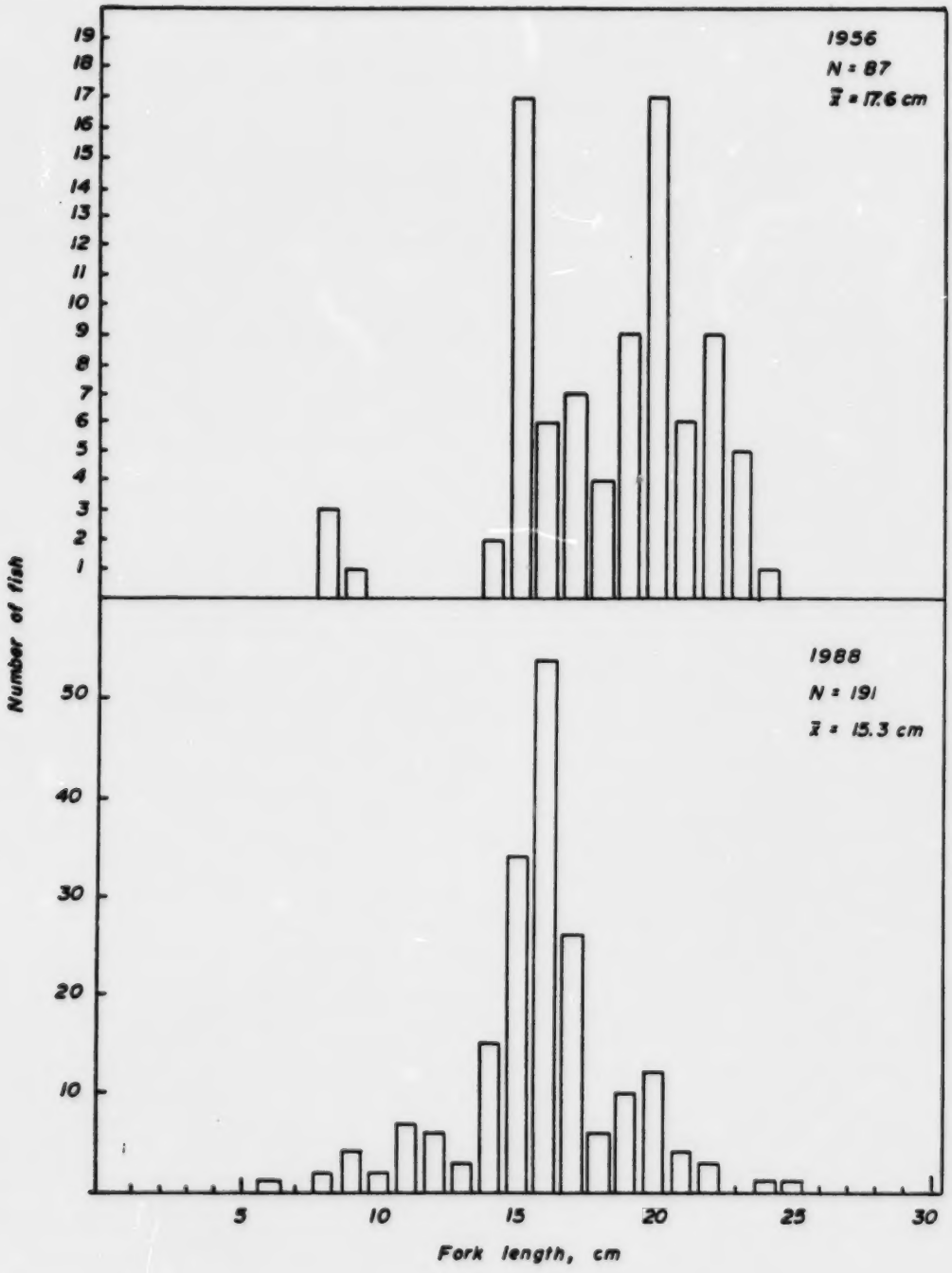

Fig. 18 Length frequency distribution of yellow perch captured in gillnets in Smoothstone Lake in 1956 and 1988. N = sample size; $\bar{x}$ = mean fork length.

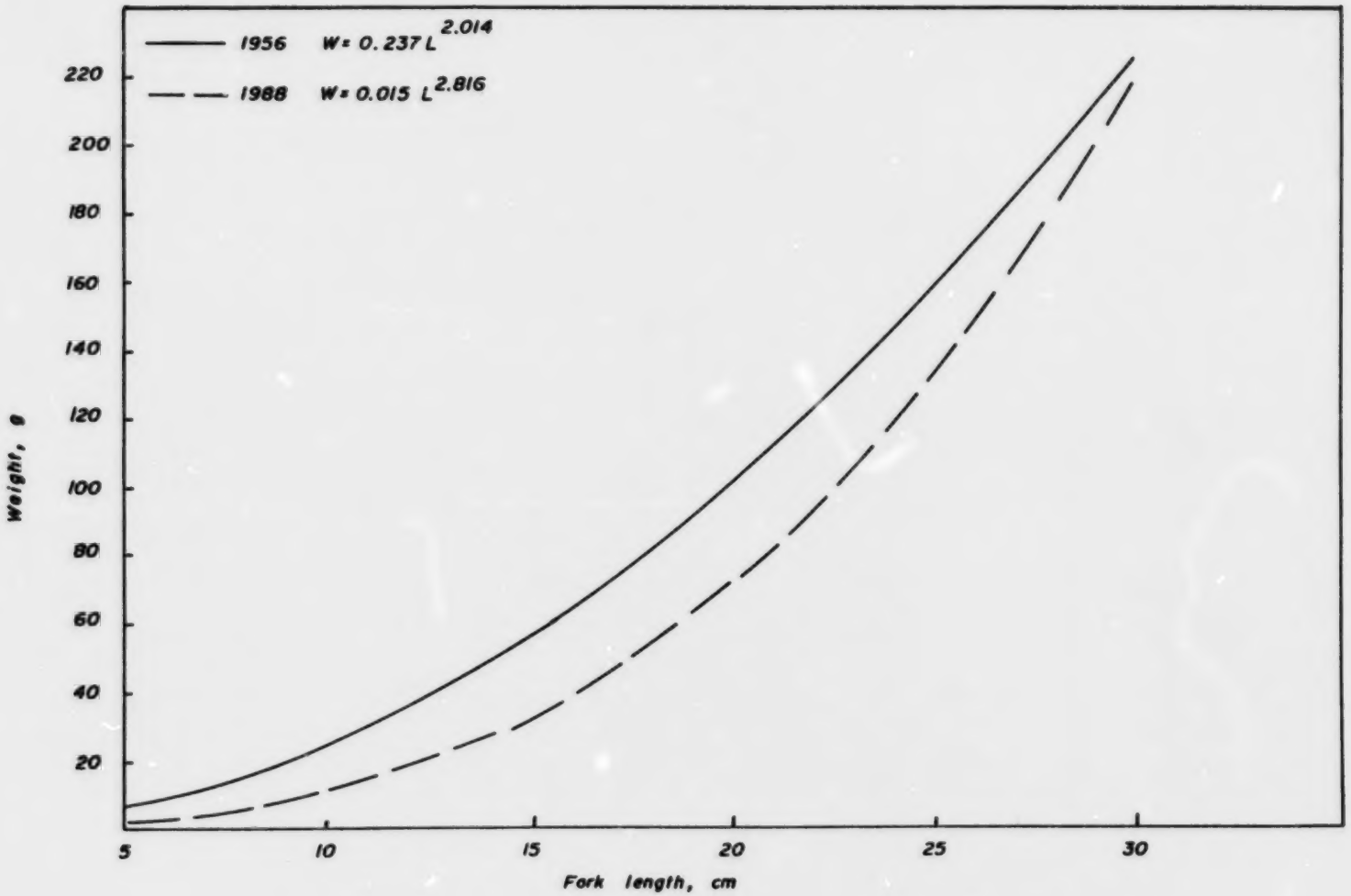

Fig. 19 Length-weight relationship of yellow perch captured in gillnets in Smoothstone Lake in 1956 and 1988.

Condition factors for male and female perch caught in 1988 (female: K=1.11; male: K=1.20) were less than that determined for perch caught in 1956 (K=1.48). Fish caught in the present study weighed less per unit length that they did in 1956.

4.4.2.4 Other Species

In addition to the three species discussed above, several other species of fish were caught in the gillnets set in Smoothstone Lake.

White suckers were the most abundant species of fish caught in gillnets in 1988, comprising 33.7% by number and 38.8% by weight (Appendix 5). White suckers have increased in abundance over the last three decades. In 1988, an average of 54.8 white suckers per net set was captured, more than three times the average of 17 fish per set caught in 1956. In 1976, 46.7 suckers per net set were caught (Table 8). All sizes of gillnet mesh captured this species in 1988 (Appendix 6), but over 85% of white suckers were caught in the three smallest mesh sizes. Average fork length of white sucker caught in 1988 was 32.7 cm, which is less that the average length of white sucker caught in 1956 (37.1 cm). Average weight of white suckers was also less in 1988 (440 g) than in 1956 (580 g). White suckers in Smoothstone Lake spawned at the end of May in 1988, as indicated by the capture of ripe fish in gillnets set on May 30.

Longnose suckers comprised 17.1% of the fish captured in gillnets in 1988 and contributed 24.2% by weight (Appendix 5). Like the white sucker population, numbers of longnose suckers have continued to increase over the last 30 years. During 1988, an average of 27.8 fish per gillnet set was captured, more than double the average of 11.8 fish per set captured in 1956. In 1976, 16.3 fish per net set was caught (Table 8). The 7.6 and 10.2 cm meshes were most effective in sampling longnose suckers in 1988, capturing over 50% of the species (Appendix 6). Average size of longnose suckers was 37.2 cm and 540 g in 1988, which is substantially larger than fish captured in 1956 (31.0 cm and 480 g). The capture of spent longnose suckers in gillnets set at the end of May indicated that spawning of this species had occurred.

Cisco comprised almost 10% of the gillnet catch in 1988 (Appendix 5) and 1.2% by weight. Numbers of cisco in Smoothstone Lake have fluctuated over the last thirty years. In 1956, only 8.4 cisco per net set were captured, in 1976, 41.4 cisco per set were caught, and in 1988, an average of 16 per set was captured (Table 8). Average size of cisco captured was 16.6 cm and 44 g in 1988, and 15.9 cm and 48 g in 1956.

Twenty-one burbot were captured in the gillnets set in Smoothstone Lake in 1988. Average size of this species was 65.6 cm and 2010 g. Ages of the burbot captured in 1988 varied between 3 and 17 yr, based on otolith age. The majority of burbot were between 9-13 yr.

Only 2 burbot were captured in the gillnets set in 1956, and 3 in 1976 net sets.

Only one walleye was captured in gillnets set in Smoothstone Lake in 1988, although others were caught by commercial fishermen. Ten walleye were captured in the nets set in 1956. None were captured in the 1976 test nets (Table 8).

The forage fish population of Smoothstone Lake is made up of spottail shiners, ninespine stickleback emerald shiners, fathead minnows, and immature yellow perch (Table 9). Spottail shiners, perch and sticklebacks were found in almost all of the 19 seining attempts suggesting a relatively uniform distribution of forage around the shoreline. Because of the qualitative nature of the sampling effort, an estimate of shoreline standing crop of forage species could not be derived. It would appear from the numbers of forage fish caught that a substantial food base is available for larger fish such as northern pike and walleye.

4.4.3 Use of the Fishery Resource

The fish resource in Smoothstone Lake is used by a commercial fishery, a small sport fishery and a one-person domestic fishery. More extensive domestic fishing and mink ranching are known to have taken place on Smoothstone Lake in the past but there are no formal records of fish harvest for these purposes.

Official harvest records are available for the commercial fishery since 1925. A quota of 18 000 kg (40 000 lb) was set on the fishery in 1941. Species included in the quota were walleye and whitefish. Originally the fishery operated in the winter season, between November 1 of one year to April 15 of the following year. In 1943, the fishery changed to operate during the summer (April 16 - October 31). The quota has been increased several times, and the season has also been changed. After 1970, pike harvest was limited by the quota, along with walleye and whitefish. The current quota is set at 56 700 kg, including pike, whitefish and walleye. The legal mesh size of gillnet has remained unchanged at 12.7 cm since 1952. No separate species quotas or gamefish tolerance limits have been implemented.

Commercial fish production from Smoothstone Lake between 1925 and 1988 is indicated in Appendix 10 and Fig. 20. Commercial production has been sporadic, ranging from a maximum of 143 691 kg (5.06 kg/ha) in 1943-44 to 131 kg (0.005 kg/ha) taken during 1965-66. The number of licenses issued annually has varied from 1 to 30. Total production is highly correlated to fishing effort ($r=0.70$; $p<0.01$). Average annual production for the period of record is 0.69 kg/ha, comprising 52.6% whitefish, 19.3% walleye, 16.5% pike, with other species (suckers and burbot) making up the remaining 11.6%.

Average production for each decade is summarized in Table 13. Total production increased from 1925, reaching a peak between 1940-49. Since then, average production has steadily declined. Prior

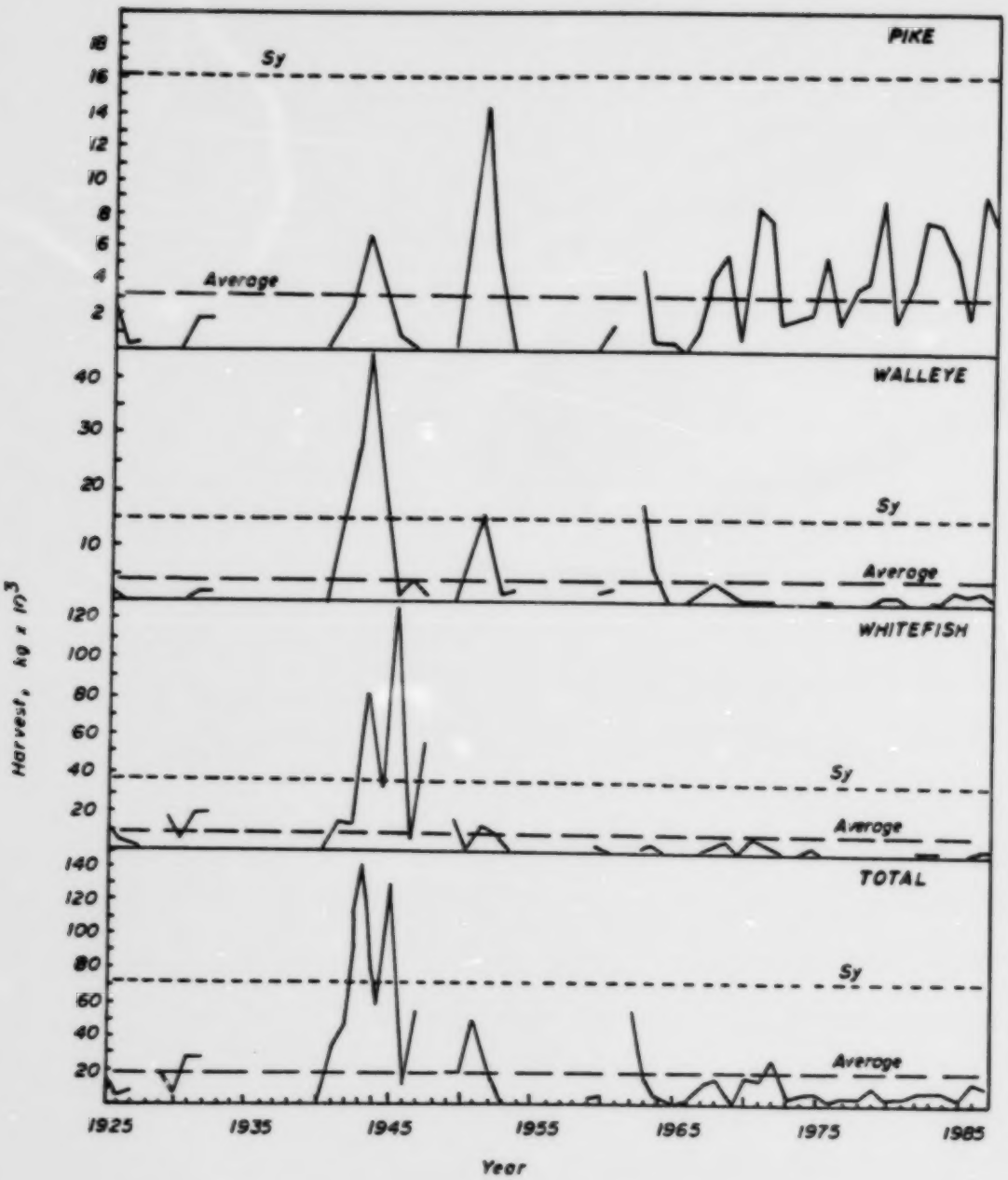

Fig. 20 Commercial production of pike, walleye and whitefish from Smoothstone Lake, 1925-1988. Sy = potential sustained yield.

Table 13. Average commercial fish production (kg) in Smoothstone Lake during each decade of recorded fishery operations.

	Whitefish	Walleye	Pike	Other	Total
1925-1929	9 052	323	804	1 731	11 909
1930-1939	13 604	924	907	2 120	17 556
1940-1949	38 973	11 893	1 791	2 825	55 481
1950-1959	4 248	5 135	4 423	2 149	15 955
1960-1969	2 296	3 903	2 184	3 896	12 280
1970-1979	2 087	328	4 682	2 495	9 591
1980-1988	1 153	1 131	5 807	2	8 092

to the 1950s, whitefish comprised more than 70% of the commercial harvest. Since 1950, however, harvests of whitefish have decreased and harvests of gamefish have increased. Because of poor production since the early 1950s, commercial fishermen at Smoothstone Lake requested that the legal mesh size on the lake be lowered to 11.4 cm from 12.7 cm in the mid 1970s. A test netting program was carried out in 1976 to investigate this possibility (Walton 1977), however, no reduction in mesh size occurred.

Whitefish from Smoothstone Lake are infected with cysts of the tapeworm *Triaenophorus crassus*. Inspection of whitefish by the Department of Fisheries and Oceans in 1979 indicated rate of infestation per 100 lb of fish averaged 408 cysts in June and 227 cysts in October. Whitefish from Smoothstone Lake are currently classified as cutter quality (DFO 1988), indicating that they contain an average >80 cysts per 100 lb. The market price for cutter whitefish at $0.247 per kg FOB Dore Lake is about one-third that given for export quality whitefish (<40 cysts per 100 lb). Lack of a suitable market for whitefish and a poor dollar return has undoubtedly encouraged commercial fishermen to set their gillnets for gamefish.

Sampling of the commercial catch was carried out between May 26-28, 1988 to determine the size of fish being harvested. Thirty-nine whitefish were measured Their length distribution is illustrated in Fig. 21. All of the fish captured by the commercial fishery were >40 cm in fork length. Since both sexes of whitefish attain size at maturity

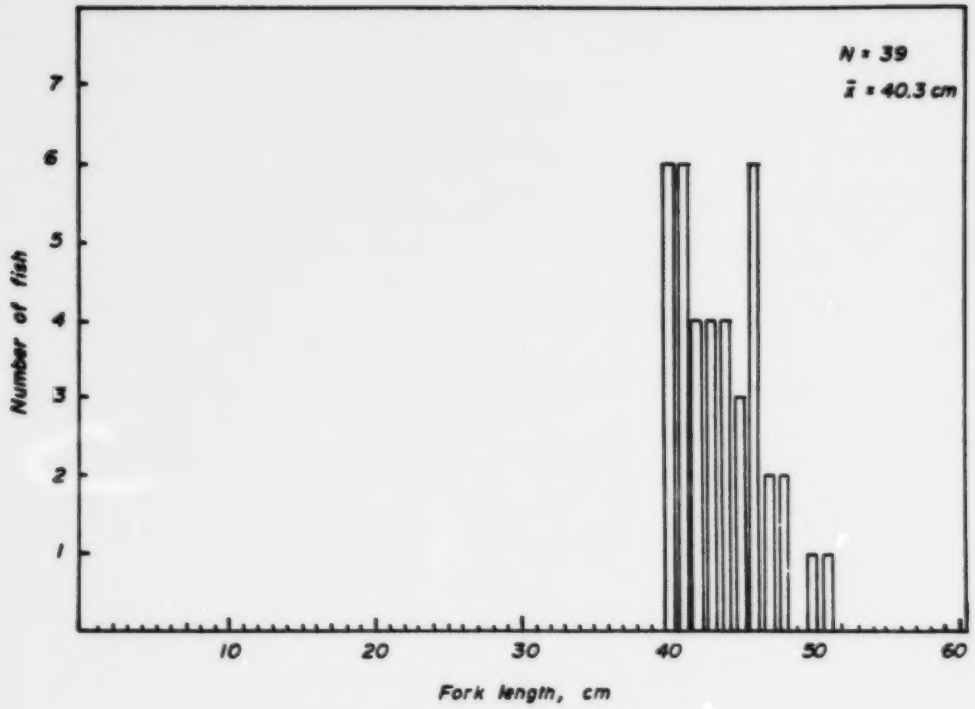

Fig. 21 Length distribution of whitefish sampled from the commercial fishery on Smoothstone Lake in 1988. N = sample size; $\bar{x}$ = mean fork length.

before 30 cm, the commercial fishery is not exploiting immature fish. Average fork length of whitefish harvested by the fishery was 40.3 cm.

A sample of 108 northern pike harvested by the commercial fishery in 1988 was examined. The fish ranged in length between 39-90 cm, although the majority of pike taken were 60-73 cm (Fig. 22). Average size of fish harvested was 66.7 cm.

Six walleye captured by the commercial fishery in 1988 were examined. These fish ranged in fork length from 47.4-52.0 cm and weighed between 700-1350 g. Average size was 50.2 cm and 1200 g.

Angling on Smoothstone Lake is very limited. An outfitter's lodge located on the west side of the lake no longer accommodates anglers but rather caters to hunters during the winter months. A government-operated campground located at the road access on the south end of the lake attracts very few anglers. Approximately 30 anglers are known to have fished in Smoothstone Lake in the summer of 1988. Several have been fishing there for years and were familiar with the lake. These were able to take their catch limits of pike relatively easily, while others less familiar with the lake were less generously rewarded.

Seventy-nine northern pike captured by anglers in August, 1988 were examined. Fork lengths of these fish ranged from 51-91 cm and average length was 66.2 cm (Fig. 22). Ages ranged from 3 to 9 yr, with almost 50% of the pike falling into the 5 yr age class.

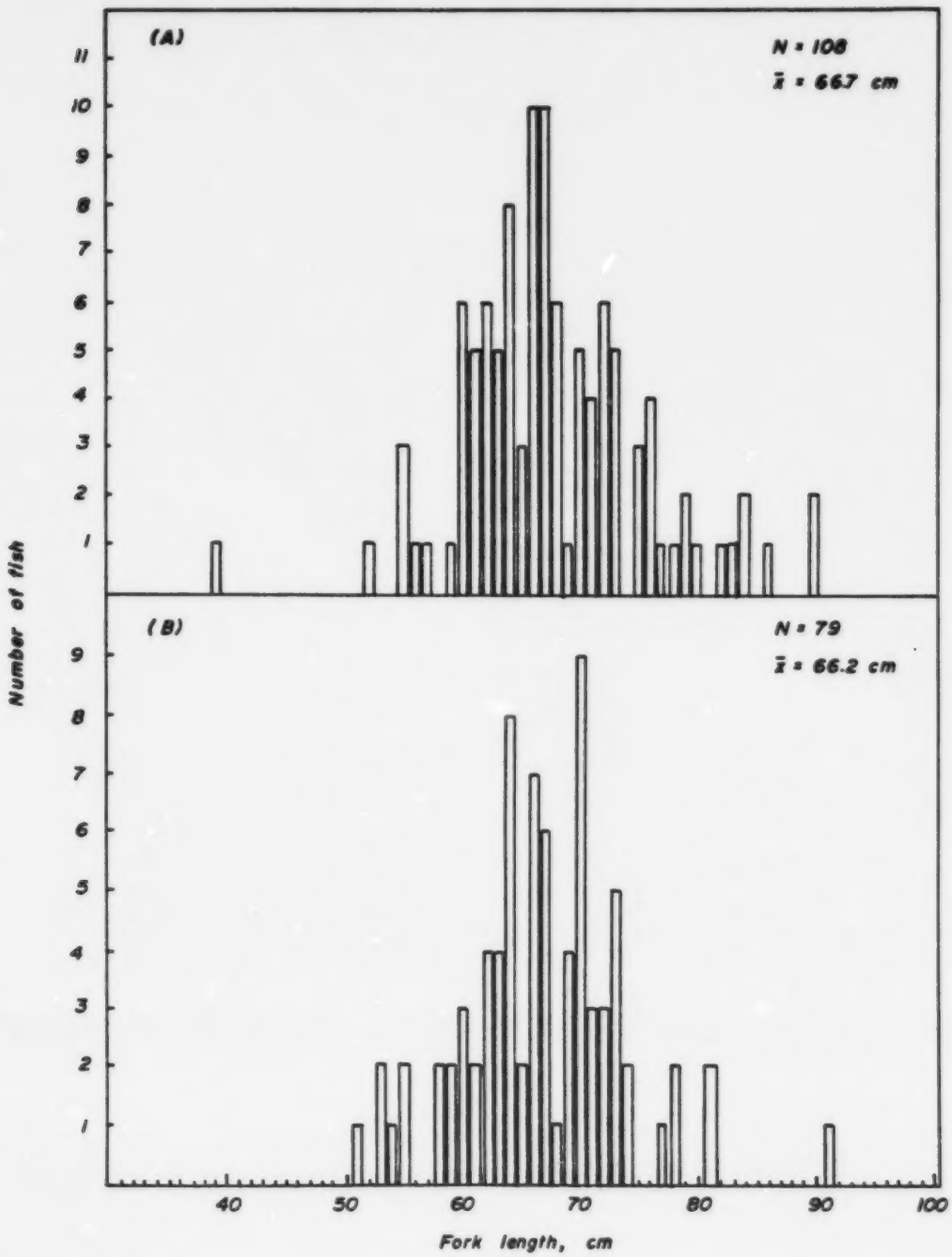

Fig. 22 Length distribution of pike sampled from the commercial (A) and sport (B) fisheries on Smoothstone Lake in 1988. N = sample size; $\bar{x}$ = mean fork length.

5. DISCUSSION

5.1 MORPHOMETRIC AND PHYSICO-CHEMICAL FEATURES

Smoothstone Lake has a surface area of 28 380 hectares, somewhat greater than Canoe Lake (21 054 ha) and Lac la Plonge (19 680 ha) and is about half the size of Dore Lake (64 231 ha). It is almost circular and lacks islands and sheltered bays suitable for sport fish habitat. The shoreline is composed of wave scoured boulder material. With a mean depth of 10 m, shallow littoral areas are scarce. Over 85% of the lake is less than 20 m deep. As a result the lake is too shallow to support a lake trout population. The lake bottom appears to be composed of undulating sand and glacial till which is subject to displacement by wave action and water currents.

Temperature profiles indicate that there is no thermal stratification. Dissolved oxygen depletion appears to occur at the sediment interface during the summer months. These factors could reduce the quantity and diversity of benthos and the ability of cold temperature dependent fish such as whitefish to feed on them.

pH and water quality parameters measured in Smoothstone Lake reflect conditions typical of a northern boreal lake with moderately alkaline water with low total dissolved solids.

5.2 PLANKTON

Phytoplankton in Smoothstone is typical of lakes on glacial terrain. Blue-green algae were dominant throughout the summer months. This category was predominated by *Microcystis aeruginosa*, *Coelosphaerium naegelianum* and *Anabaena flos-aquae*. Diatoms and green algae were moderately abundant throughout the study period.

Average standing crop of net plankton in the main part of Smoothstone Lake was estimated at 102.1 kg/ha. This value is substantially higher than the 77.9 kg/ha reported in the southern part of Montreal Lake in 1987 (Merkowsky and Sawchyn, 1988) or the plankton standing crop of 61.4 kg/ha measured in Dore Lake in 1986 (Sawchyn, 1987a). Plankton production is a measure of the potential of a lake to produce other biota including bottom fauna and fish. As such it should be more productive than Montreal and Dore Lakes, for example.

The fact that plankton species being produced are predominantly blue-green algae, which are not a good food base for zooplankton and benthic fauna, may explain this inconsistency. In fact, mean chlorophyll *a* levels of 2.4 µg/L which reflect the quantities of green algae present suggest a low total standing crop barely within the range of 3.337 ± 1.131 considered typical of lakes in a forest watershed (Liaw 1982). Chlorophyll *a* levels in Montreal Lake averaged 11.2 µg/L in 1987 (Merkowsky and Sawchyn 1988).

5.3 BOTTOM FAUNA

The bottom fauna of Smoothstone Lake is characterized by a predominance of midge larvae (65%), sludge worms (20.9%), freshwater shrimp (7.3%), and fingernail clams (5.8%). The species present are typical of those occurring in organic substrates in sublittoral areas and forming principal food components for lake whitefish. Standing crop of bottom fauna was 8.0 kg/ha in 1988, which represents a substantial increase from the 2.2 kg/ha measured in 1956 (Scott 1956). The values reported by Scott are based on fewer samples (27 as compared with 78 taken in 1988) which were taken later in the summer when many of the chironomidae had emerged. The increase in benthic biomass may be linked to increased plankton productivity observed in this study.

Benthic biomass gives an indication of the general productivity of a lake (Wetzel 1975). Smoothstone Lake is relatively unproductive by comparison with other Saskatchewan Lakes. For example, Montreal Lake produces about 17.3 kg/ha (Merkowsky and Sawchyn 1988) and Dore Lake averaged 22.4 kg/ha (Sawchyn 1987a). In contrast, Tobin Lake, which is one of the most productive lakes in the province, has a standing crop of nearly 100 kg/ha (Durbin 1981).

5.4 FISH POPULATIONS

A comparison of standard gang gillnet catches reveals that although total numbers of fish captured per net set have increased since

1956, Smoothstone Lake has remained relatively low in abundance of gamefish. Fewer than 6 gamefish per net set were caught in the gillnets in 1988 (gamefish included are pike and walleye), which is very similar to Dore Lake (7.2) but substantially less than other nearby Saskatchewan Lakes (Table 14). For example, an average of 72.1 gamefish per net set was captured in Pinehouse Lake (Liaw 1988). Both longnose and white sucker populations have continued to increase in abundance during the last three decades, and together with perch, make up the dominant fish species in Smoothstone Lake. Relative abundance of whitefish has decreased since 1956, although numbers caught per net set were almost equal in 1956 and 1988. Whitefish numbers are substantially higher than in other lakes compared including nearby Dore Lake.

Pike is the only gamefish of significance occurring in Smoothstone Lake. Numbers of pike harvested by the commercial fishery have increased during each decade of recorded fishery operations, probably a result of the better price obtained by pike on the market as compared to whitefish. Pike is also the main species harvested by anglers on Smoothstone Lake. Pike numbers are similar to those of Dore Lake but much lower than in Pinehouse, Montreal or Jan Lakes.

Numbers of pike captured per net set have increased since 1956 but still remain low. Abundance of pike in Smoothstone Lake is probably limited by lack of suitable spawning habitat. Very few weedy, marshy areas occur around the shoreline of Smoothstone Lake. Although tributaries to Smoothstone Lake provide suitable spawning habitat,

Table 14. Comparison of average number of fish per standard gang gillnet set between Smoothstone Lake and several similar northern lakes.

	Smoothstone			Pinehouse	Dore	Montreal	Jan
	1956[1]	1976[2]	1988	1986[3]	1986[4]	1987[5]	1989[6]
Species							
Burbot	0.4	0.7	0.8	0.5	1.9	0.1	1.2
Cisco	8.4	41.4	16.0	103.5	8.6	71.8	60.1
White Sucker	17.0	46.7	54.8	19.5	63.2	77.1	34.2
Longnose Sucker	11.8	16.3	27.8	0.8	6.3	0.0	0.0
Perch	17.4	60.8	34.4	2.4	49.4	5.5	16.5
Pike	2.0	1.9	5.5	23.4	5.9	39.9	21.8
Walleye	2.0	0.0	<0.1	48.5	1.3	50.1	15.5
Whitefish	26.0	5.7	23.5	17.3	15.2	8.3	19.0
Sauger	0.0	0.0	0.0	1.2	0.0	0.0	0.0
All Species	85.0	173.5	162.9	217.1	151.8	252.7	169.1

1. Scott 1956
2. Walton 1977
3. Liaw 1988
4. Sawchyn 1987a
5. Herkowsky and Sawchyn 1988
6. Gloutney 1990 (In preparation)

blockage of two of the streams by beavers prevents spawning migration and any pike that are able to reproduce in them are trapped. The inflowing Smoothstone River provides some areas suitable for pike reproduction, however an old water control structure near Little Clarke Lake probably prevents pike spawning runs into this shallow lake.

A spawning investigation was undertaken by Regional Fisheries Biologists on three streams flowing into Smoothstone Lake in the spring of 1988 following observations that some road crossings were impeding fish migration (R. Orr, L. Wallin , pers. comm.). A culvert placed at the Swan Lake road crossing of the Philion River was set too high creating a "waterfall" which prevented fish migration. "Hundreds of common suckers were observed below the culvert along with 3 pike" on May 5 and 6, 1988. Observations and testnetting indicated that some suckers were getting through the culvert against a strong current, but no pike were observed upstream from the crossing. Specific recommendations have been made to mitigate the problem.

Hook Creek originating in Muskakowan Lake and flowing into the Smoothstone River upstream of Smoothstone Lake was also examined. Pike in spawning condition were captured and longnose suckers observed a short distance upstream from Hwy #916 crossing on May 5 and 6, 1988, confirming this tributary as a spawning area.

Mahigan Creek flowing from Little Mahigan Lake into Selenite Bay of Smoothstone Lake was also examined. No fish were observed in the

creek although some large beaver dams are present and are possibly preventing upstream migration of fish.

Growth of pike from Smoothstone Lake is compared to growth of populations from other Saskatchewan waterbodies in Table 15. Growth of pike from Smoothstone Lake is faster than those from Hunter Bay, Pinehouse Lake, Montreal Lake and Churchill River. Only growth of pike from productive Tobin Lake surpasses that of Smoothstone Lake pike. The robustness of Smoothstone Lake pike is also reflected in their relatively high condition factor (0.79) as compared to the condition of pike from Montreal Lake (0.67; Merkowsky and Sawchyn 1988) and Jackfish Lake (0.73; Durbin 1980).

All pike that were >46 cm long from Smoothstone Lake were mature, which is similar to pike from Pinehouse Lake (Liaw 1988) that mature at 42.0 cm (males) and 45.1 cm (females). Pike from the Smoothstone-Pinehouse drainage attain maturity at a relatively early age (2-3 yr) as compared to populations in the Churchill River at Sandy Bay that are not mature until 6 yr of age (Liaw 1986).

The presence of numerous age classes suggests that the pike population of Smoothstone Lake, although not abundant, is not being overexploited. Although a rapid growth rate and early age at maturation is often a response to overexploitation, it appears that in Smoothstone Lake an adequate forage base together with lack of competitor species (walleye) have influenced the growth rate of pike. Pike in Smoothstone Lake fed almost exclusively on fish.

Table 15. Growth of pike and whitefish (fork length, mm) in Smoothstone Lake and other Saskatchewan waterbodies. Ages based on scales unless otherwise indicated. Lakes listed in order of decreasing fork length at age 5+.

	Age, yr														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PIKE															
Tobin L[1]	226*	442	501	557	623	681	723	851	-	-	-	-	-	-	-
Smoothstone L[2]	328	471	529	560	618	591	647	454*	-	-	-	-	-	-	-
Hunter Bay+[3]	183	320	422	498	538	597	630	582*	627	627*	-	-	-	-	-
Pinehouse L[4]	222*C	344C	454C	499C	528C	570C	589C	-	660*C	690*C		-	702*C	-	-
Montreal L[5]	-	212	314	407	511	617	738	786	-	-	-	-	-	-	-
Churchill R[6]	-	-	-	301	425	461	501	543	583	653	700	-	-	-	-
WHITEFISH															
Montreal L	161	269	322	374	419	427	447	457	490*	-	-	-	-	-	-
Dore L[7]	170*	195	256	291	370	398	410	429	432*	450*	454	466*	-	-	-
Pinehouse L	151	236	276	336	367	414	434	462	458*	-	-	-	-	-	-
Lac la Plonge[8]	-	206	244	296	341	362	375	379	394	412*	-	-	-	-	-
Churchill R	-	197	264	294	330	373	399	415	456	477	478	489	-	-	-
Smoothstone L[**]	171	197	235	278	313	354	386	390	417	441	360*	527*	411*	-	472*
Highrock L[9]	-	183	216	246	281	297	324	340	359	378	393	413	423	441	495

* Sample based only on 1 or 2 specimens
\+ Male pike only
C Cleithrum age
1-Durbin 1981; 2-present study; 3-Koshinsky 1979; 4-Liaw 1988; 5-Merkowsky & Sawchyn 1988; 6-Liaw 1986; 7-Sawchyn 1987a; 8-Sawchyn 1987b; 9-Dean 1980
** Ages recorded for all Smoothstone Lake whitefish listed in this table are from scales so that comparisons could be made.

Commercial exploitation of whitefish in Smoothstone Lake has declined since the early 1950s. Poor production is probably due in part to reduced fishing effort, but a poor price for Smoothstone Lake whitefish that are classified as cutter quality has encouraged fishermen to set their nets for pike. A comparison of numbers of whitefish per standard gang in 1956, 1976 and 1988 reveals that whitefish numbers were low in the mid 1970s but were back to the 1956 levels during the current survey. Although average length of whitefish has remained constant, condition of the fish was much poorer in 1988 than in the 1950s.

Growth of whitefish from Smoothstone Lake is compared to growth of whitefish populations in other Saskatchewan waterbodies in Table 15. Whitefish from Smoothstone Lake had the poorest growth rate of fish from any of the other waterbodies except those from the more northern Highrock Lake. Whitefish from Pinehouse Lake, into which Smoothstone Lake drains, achieve a substantially larger size at age than Smoothstone Lake whitefish. A lower condition factor for whitefish caught in 1988 as compared to 1956 samples also indicates that the fish are thin.

Smoothstone Lake whitefish reach size at maturity (28.5 cm for females and 26.5 cm for males) at a smaller size than those from Pinehouse Lake (37.1 cm for females and 34.6 cm for males; Liaw 1988). However, because of differences in growth rate, whitefish from both Pinehouse and Smoothstone Lakes would be mature by 4-5 yr of age. Size at maturity of whitefish from Smoothstone Lake in 1988 was similar to

that of the fish captured in 1976 which also matured between 29.0 cm and 32.0 cm.

The presence of numerous year classes, particularly a large proportion of older fish, and high mean age and relatively late age at maturity suggest that whitefish stocks in Smoothstone Lake are not being overexploited. The poor growth achieved by Smoothstone Lake whitefish may be a result of the unproductive nature of the lake in terms of benthic fauna. The abundant sucker populations in the lake are probably competing for the same food resources as the whitefish and are limiting the success of whitefish stocks.

Walleye populations in Smoothstone Lake remain poor. Very few walleye were captured in gillnets during any of the three surveys, although some walleye are harvested by the commercial fishery. Walleye were scarce in commercial gillnet catches in the period from 1925 to 1941 followed by a large harvest from 1941 to 1945 and subsequent decline to the present date. This raises a suspicion that walleye reported under the Smoothstone Lake quota in the 1940's may have been harvested elsewhere. Alternatively the population is not regulated by harvest pressure but rather factors that affect spawning and recruitment, and possibly competition with perch. No evidence of walleye spawning was reported in the studies undertaken on the tributary streams. Spawning areas for walleye from Smoothstone Lake are unknown.

Perch continues to be an abundant species in Smoothstone Lake, and populations have increased since 1956. Because of their small

size, perch do not contribute much to the weight of fish taken in the gillnets. On the basis of 96 specimens with a total length greater than 10.0 cm the relative weight (actual weight/standard weight x 100) of perch from Smoothstone Lake is only 71% of the standard weight of perch in North America (Willis et al 1989) which indicates poor condition (100% being average). Perch are not harvested to any extent by either the sport or commercial fisheries.

Populations of white and longnose suckers tripled in numbers and weight in the 1988 gillnet catches as compared with 1956. The increase in these species may be in response to increased quantities of benthic fauna as food and low numbers of predatory species such as northern pike and walleye. Similar trends were observed in Dore Lake (Sawchyn, 1987)

5.5 LAKE PRODUCTIVITY

Determination of fish productivity of a lake is important in order to recommend management plans for the use of the resource. Estimates of sustained fish yield for Smoothstone Lake were made using morphoedaphic index (Ryder 1965), standing crop of bottom fauna (Matuszek 1978), and macrobenthos biomass/mean depth (Hanson and Leggett 1982). The estimates, based on various models, are:

Model 1	Potential fish yield, kg/ha/yr
Total, Y=0.966 MEI (Ryder et al. 1974)	4.76
Total, Y = 0.007M + 0.018 TDS −0.053Z + 0.00007Ao +0.793	5.08
Total, Ct/A=−0.5524 + 4.9307logBFWT (Matuszek 1978)	3.91
Highly valued species, log (Cs/A) = −0.169 + 0.562logBFWT (Matuszek 1978)	2.19

A comparison of the estimates for total potential yield reveals that the equations incorporating a measure of water quality provided higher estimates of sustained yield than for the equation using bottom fauna alone. The two higher values were averaged to obtain an estimated yield, Y for all fish species from Smoothstone Lake of 4.92 kg/ha/yr.

Estimates of sustained fish yields of the highly valued species (pike, whitefish and walleye) were determined, using morphoedaphic index (Schlesinger and Regier 1983):

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1 MEI=morphoedaphic index, TDS/z; M=wet weight of bottom fauna, 60.57 kg/ha; TDS=total dissolved solids, 243 mg/L; z=mean depth, 10.0 m; Ao=water area, 283.75 km^2; Ct/A=total sustainable yield; BFWT=dry weight of bottom fauna, 8.04 kg/ha; Cs/A=sustainable yield of highly valued species, whitefish, walleye and pike.

	Estimated sustained yield Kg/ha/yr	Kg/yr
$\log_{10}$Whitefish Sy = 0.6497($\log_{10}$MEI) - 0.6683	1.706	48 408
$\log_{10}$Walleye Sy = 1.3829($\log_{10}$MEI) - 1.8136	1.266	35 923
$\log_{10}$Pike Sy = 1.4163($\log_{10}$MEI) - 1.9393	1.055	29 936
All species	4.027	114 262

The estimated species yields for whitefish, walleye and pike total 4.027 kg/ha/yr. This is almost twice that determined from Matuszek's (1978) regression equation (2.19 kg/ha/yr) for the potential yield of highly valued species. A more realistic estimate is derived by excluding walleye since virtually no walleye are available for harvest. This would reduce the estimated sustained yield to 78 339 kg/yr (2.76 kg/ha/yr).

A comparison of long-term fish yields from Smoothstone Lake with the estimated sustained yields indicates that Smoothstone Lake has not been overfished. Only occasionally during the 1940s did reported harvests exceed sustained yields, and yields in recent years have dropped well below the sustained yield level.

The current commercial limit of 56 700 kg (2.00 kg/ha) is less than the estimated potential fish yield of 78 339 kg (excluding walleye).

5.6 MANAGEMENT IMPLICATIONS

Of the eight species of fish captured in gillnets set in Smoothstone Lake in 1988, only whitefish, pike and walleye are of economic significance. Rough fish species (cisco, burbot and sucker) have been harvested by the commercial fishery in the past, but are now taken only incidentally because there is no market demand.

Although commercial production of fish from Smoothstone Lake has undergone large year-to-year fluctuations, a breakdown of average production during each decade indicates that long-term total production averaged <20 000 kg/yr except for a peak during the 1940s. A general declining trend in commercial production has occurred since the 1940s peak associated with the war years. This trend may be a result of fluctuations in fish stocks, as well as changes in fishing effort. Long-term production between 1925-88 (19 680 kg/yr) is far below the current commercial limit of 56 700 kg/yr, and is far less than the potential fish yield of 78 339 kg/yr (excluding walleye).

The whitefish in Smoothstone Lake are very slow growing. In a study of the effect of exploitation on whitefish populations in an unexploited lake, Healey (1978, 1980) found that growth, fecundity, and recruitment increased after the start of exploitation. Mills and Chalanchuk (1988) found that exploitation caused recruitment to increase more so than growth and that only in the highest exploited populations did increased growth persist for more than a year.

On the basis of these findings and the history of commercial fishing in Smoothstone Lake it is reasonable to speculate that the population has been underfished and is slow growing as a result. A reduction in mesh size is a simple means of increasing harvest without increasing costs and effort. A comparison of whitefish harvest in different mesh sizes of the standard netsets (Fig. 13) shows that mesh sizes of 10.2, 12.7 and 14.0 cm all select fish larger than 30 cm long. A reduction in mesh size from 12.7 cm to 11.4 cm will allow higher numbers of whitefish to be taken without threat to the reproductively immature specimens.

A whitefish quota should be established at 45 700 kg to be more consistent with the estimated sustained yield of 48 408 kg/yr.

Currently, whitefish from Smoothstone Lake are classified as cutter and do not receive the dollar value received for export quality whitefish. Cyst counts taken during the 1988 survey revealed that the whitefish had a rate of infestation of 43 cysts per 100 lb, which is less than cutter quality whitefish contain (>80 cysts per 100 lb). A further evaluation of Smoothstone Lake whitefish by the Department of Fisheries and Oceans is advisable to reassess the quality of this species. A better price value for whitefish would encourage commercial fishermen to set their nets for this species rather that gamefish.

Walleye populations are not abundant in Smoothstone Lake. Although only one walleye was captured in standard gang gillnets, walleye are taken by the commercial fishery. Removing walleye as a

species in the commercial quota will help preserve the remnants of an indigenous population which could serve as a base for rebuilding the walleye stock. The best option for restoring the walleye population would appear to be through a concerted effort in locating and restoring natural spawning habitat. A reduction in mesh size as a means of stimulating whitefish production will cause more northern pike to be taken. These would generally be more than 50 cm long. Mechanisms to reduce overharvest of pike should include separate species quotas with incentives to harvest whitefish in deeper waters not frequented by pike.

A northern pike commercial quota of 11 000 kg/yr should be established. This combined with a whitefish quota of 45 700 kg would maintain the total lake quota at 56 700 kg/yr. Poor reproductive habitat is probably limiting the success of pike populations in Smoothstone Lake. The major portion of the littoral zone has a sand or stone substrate. Suitable spawning areas appear to be available in the tributaries. Keeping the tributaries free of beaver dams would increase areas available for both pike and walleye reproduction.

Increasing the abundance of gamefish through management of spawning areas will help control population levels of rough fish species because both pike and walleye prey upon suckers as a food item. A reduction in sucker populations, that are competing with whitefish for food resources, would allow whitefish stocks to improve.

Due to its general unproductive nature, Smoothstone Lake will never support large fisheries as are found on other Saskatchewan

Lakes. However, a better balance of the species present will allow optimum use of the fishery resource.

6. SUMMARY CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY AND CONCLUSIONS

1. A detailed fisheries survey of Smoothstone Lake was undertaken in the summer of 1988. This provides the first complete documentation of the biology and fish resources of the lake.
2. Smoothstone Lake is located at 54°40' Lat. and 106°50' Long. approximately 240 km northwest of Prince Albert. It is accessible by way of secondary roads from Highways 2 and 55.
3. Smoothstone Lake is situated on boreal glacial deposits. It receives drainage from approximately 2900 km^2 of terrain by way of several small streams. It empties into the Churchill drainage by way of the Smoothstone River and Pinehouse Lake.
4. Smoothstone Lake is roughly circular, with an open water area of 284 km^2 and a maximum length of 26 km. Mean depth and maximum depth are 10.0 m and 33.0 m, respectively.
5. The shallow depth, large area of open water and scarcity of islands provide for complete mixing during the summer with little thermal or dissolved oxygen change between surface and bottom.
6. Total dissolved solids ranged from 238 to 264 mg/L, typical of lakes in the forest zone. pH varied between 8.0 and 8.3.

7. Blue-green algae are the dominant phytoplankton forms during the warm summer months. Diatoms and green algae are abundant throughout the openwater season. Average standing crop of net plankton in the main part of the lake was 102.1 kg/ha, substantially higher than in other large lakes in the area.
8. Midge larvae (Chironomidae) were the predominant benthic organisms in Smoothstone Lake. Total numbers of organisms captured in 1988 was 810/m (8.0 kg/ha), about five times more than the 158 organisms per m2 (2.2 kg/ha), collected in preliminary sampling in 1956.
9. Seventeen species of fish were collected in the course of the biological survey. Yellow perch, spottail shiners, ninespine sticklebacks, emerald shiners and fathead minnows were common in seine hauls.
10. White suckers were the dominant fish caught in gill nets, making up 33.7% by number and 38.8% by weight of the total catch. Perch and longnose suckers made up 21% and 17% of the population, respectively. Other species caught were whitefish (14.4%), cisco (9.8%), northern pike (3.4%) and burbot (0.5%). Only 1 walleye was caught.
11. Gillnets caught an average of 163 fish per net set, almost double the number caught in 1956. Almost 85% of the fish caught in gillnets were taken in the three smallest mesh sizes ranging from 3.8 to 7.6 cm.

12. Northern pike is the dominant sport fish species but represents only 3.4% of the total population in Smoothstone Lake. Ages of pike caught by gillnetting ranged from 1 to 8 years with the majority in the 3 year age class.
13. Only one walleye was captured in 1988; ten were caught in 1956 and none in 1976 suggesting walleye were never a dominant species in Smoothstone Lake since the harvest of large numbers in the early 1940's.
14. Whitefish comprised 14.4% of the fish caught by netting. (23.5 fish per standard set). Relative abundance in 1956 was 30.6% and 3.3% in 1976. Ages ranged from 1 to 30 years with the majority in the 5 year class.
15. Size at maturity of whitefish was 28.5 cm for females and 26.5 cm for males at which time they were 4 - 5 years old.
16. Infestation rate of whitefish by *Triaenophorus crassus* was 43 cysts per 100 lb which would rank the lake as continental in marketing quality. Smoothstone Lake is presently classed as a cutter lake.
17. Numbers of ciscoes caught per standard gang ranged from 8.4 in 1956 to 41.4 in 1976 and 16 in 1988. The average weight of ciscoes in 1988 was only 44 g.
18. Yellow perch ranked second in abundance comprising 21.1% of fish caught by gillnetting. The majority of these were between 14 and 17 cm in fork length. Yellow perch were the most abundant species

captured in seine nets and were collected in all but two seine hauls.

19. The abundance of perch and other forage species provides a plentiful food source for larger fish such as pike and walleye.
20. The fish resource in Smoothstone Lake is used by a commercial fishery, a small itinerant sport fishery and a one person domestic fishery. There are no active angler based outfitters on the lake.
21. The current commercial quota is set at 56 700 kg including pike, whitefish and walleye. The legal mesh size is 12.7 cm. The number of licenses issued has ranged from 1 to 30. The average annual production for the period of record has been 0.69 kg/ha comprising 52.6% whitefish, 19.3% walleye, 16.5% pike and 11.6% other species. The lack of a market for cutter whitefish is influencing the commercial harvest in favor of pike and walleye.
22. With the use of 12.7 cm mesh nets the commercial fishery is not harvesting immature fish.
23. Angling on Smoothstone Lake is very limited (≈30 anglers in 1988) with northern pike being the predominant catch.
24. The morphometric characteristics of Smoothstone Lake suggest a paucity of littoral habitat suitable as nursery areas for young pike and walleye. Spawning streams appear to be blocked by beaver dams and improperly placed culverts. Poor reproductive sucess for these species appears to be the main cause for their low numbers.

25. Standing crops of plankton and bottom fauna suggest adequate forage reserves for a whitefish population much larger than is present in the lake now. A highly irregular bottom profile indicates that localized pockets of anoxic conditions in the summer may deny whitefish access to these food reserves and cooler water necessary for their success.
26. Calculation of sustained fish yield for Smoothstone Lake provided an estimate of 4.92 kg/ha/yr for all species.
27. Estimates of yield for highly valued species were as follows: whitefish 1.706 kg/ha/yr (48 408 kg); Walleye 1.266 kg/ha/yr (35 923 kg); and Northern pike 1.055 kg/ha/yr (29 936) for an estimated total production potential of 114 262 kg/yr. Since walleye are virtually non-existent a more realistic total production potential is 78 339 kg/yr.
28. The current commercial limit of 56 700 provides 22 000 kg for other fisheries. Since average annual commercial production at <20 000 kg/yr (0.69 kg/ha) is well below the existing quota and estimated sustained yield the small sport fishery is unaffected.
29. Commercial harvest of whitefish is suppressed by their infestation with *Triaenophorus* cysts. Walleye and pike populations are not sufficiently abundant to act as replacement species.
30. Lack of littoral habitat and lack of access to spawning areas appear to be limiting the success of northern pike and walleye in Smoothstone Lake.

6.2 RECOMMENDATIONS

1. The annual commercial fishery quota should be maintained at 56 700 kg/yr with separate species quotas of 45 700 kg for whitefish and 11 000 kg for northern pike thus allocating 18 000 kg of northern pike for angler harvest.
2. A zero tolerance for walleye should be imposed to help restore the walleye population. The harvest of pike should be fixed at a maximum of 20%.
3. A reduction in mesh size to 11.4 cm is recommended to facilitate the harvest of whitefish. This should stimulate the growth of the whitefish present.
4. A reassessment of *T. laenophorus* infestation in whitefish should be undertaken to confirm findings of reduced infestation levels found in this study with the possibility of reclassifying the lake to provide better market advantage for whitefish.
5. An angling quota of 3 walleye per day should be introduced to allow the population to improve.
6. An inventory of spawning habitats should be prepared. Spawning streams should be cleared of obstructions such as beaver dams and improperly placed culverts to aid in the reestablishment of walleye and improve the production of northern pike.
7. A reassessment of the fish populations should be undertaken in 5 years to evaluate the results of the management strategy.

7. LITERATURE CITED

Carlander, K.D. 1969. Handbook of freshwater fishery biology. Vol. I, Iowa State University Press, Ames, Iowa.

Dean, E.L. 1980. Highrock lake fishery survey. Fish. Tech. Rep. 80-2, Dept. Tourism and Renew. Res.

Department of Fisheries and Oceans. 1988. Lake classification manual. Inspection Services Branch, Fisheries and Oceans.

Durbin, J.K. 1980. Jackfish and Murray Lakes: gamefish populations under impact. Fish. Tech. Rep. 80-6, Dept. Tourism and Renew. Res.

Durbin, J.K. 1981. Tobin Lake fishery, 1979, 17 years after impoundment. Fish. Tech. Rep. 81-5, Dept. Tourism and Renew. Res.

Gloutney, B.L. 1990 Northern Lakes Fish Monitoring Program: Jan Lake - 1989. Reassessment of the Jan Lake fishery. In preparation, Dept. Parks and Renew. Res.

Hanson, J.M., and W.C. Leggett. 1982. Empirical prediction of fish biomass and yield. Can. J. Fish. Aquat. Sci. 39: 257-263.

Healey, M.C. 1978. Fecundity changes in exploited populations of lake whitefish (*Coregonus clupeaformis*) and lake trout (*Salvelinus namaycush*). J. Fish. Res. Board Can. 35: 945-950.

Healey, M.C. 1980. Growth and recruitment of experimentally exploited lake whitefish (*Coregonus clupeaformis*) populations. Can. J. Fish. Aquat. Sc:. 37: 255-267.

Liaw, W.K. and F.M. Atton. 1981. Acid rain on northern lakes: background studies in Saskatchewan. Musk-ox 28: 26-42.

Liaw, W.K. 1982. Water quality in recreational lakes, Saskatchewan. Wastes and Prairie Water Quality, Water Studies Institute Symposium No. 8.

Liaw, W.K. 1986. Fishery and limnology of four lakes west of Sandy Bay. Fish. Tech. Rep. 86-2, Dept. Parks and Renew. Res.

Liaw, W.K. 1988. An assessment of the Pinehouse Lake Fishery. Fish. Tech. Rep. 88-2, Sask. Parks, Recreation and Culture.

Lorenzen, C.J. 1967. Determination of chlorophyll and phaeopigments; spectrophotometric equations. Limnol. and Oceanogr. 12: 343-346.

Matuszek, J.E. 1978. Empirical predictions of fish yields of large North American lakes. Tran. Am. Fish. Soc. 107: 385-394.

Merkowsky, J.J. and W.W. Sawchyn. 1988. Biological survey of Montreal Lake, 1987. Fish. Tech. Rep. 88-4, Sask. Parks, Recreation and Culture.

Mills, K.H. and S.M. Chalanchuk. 1988. Population dynamics of unexploited lake whitefish (*Coregonus clupeaformis*) in one experimentally fertilized and three exploited lakes. Finnish Fish. Res. 9: 145-153.

Musker, W.A. 1985. Materials and methods used to age fish in Saskatchewan. Manuscript Rep., Sask. Fish. Lab.

Ni, I-H. and E.J. Sandeman. 1984. Size at maturity for northwest Atlantic redfishes (*Sebastes*). Can. J. Fish. Aquat. Sci. 41: 1753-1762.

Richards, J.H. and K.I. Fung. 1969. Atlas of Saskatchewan , Univ. of Sask., Saskatoon.

Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. Trans. Am. Fish. Soc. 94(3): 214-218.

Ryder, R.A., S.R. Kerr, K.H. Loftus, and H.A. Regier. 1974. The morphoedaphic index, a fish yield estimator - review and evaluation. J. Fish. Aquat. Sci. 31-663-688.

Sawchyn, W.W. 1987a. Biological reassessment of the Dore Lake fishery. Fish. Tech. Rep. 87-5, Sask. Parks, Recreation and Culture.

Sawchyn, W.W. 1987b. Evaluation of lake trout and lake whitefish resources in Lac la Plonge. Fish. Tech. Rep. 87-1, Sask. Parks, Recreation and Culture.

Schlesinger, D.A. and H.A. Regier. 1983. Relationship between environmental temperature and yields of subarctic and temperate zone fish species. Can. J. Fish. Aquat. Sci. 40: 1829-1837.

Scott, D.C. 1956. Smoothstone Lake survey (unpublished data).

Walton, D.G. 1977. Smoothstone Lake test-netting - 1976. DNS.

Wetzel, R.G. 1975. Limnology. W.B. Saunders Co., Toronto, Ont.

Willis, D.W., C.S. Guy and B.R. Murphy. 1989. Development and evaluation of a proposed standard weight (WS) equation for yellow

perch. South Dakota Dept. of Game, Fish and Parks Wildlife Div. Progress Rept. 89-13. 26 pp.

Appendix 1. Limnological observations at Station A, Smoothstone Lake, 1988. See Fig. 2 for station locations.

	Temperature, C							Dissolved oxygen, mg/L						
	May 25	June 10	June 24	July 9	July 22	Aug 4	Aug 17	May 25	June 10	June 24	July 9	July 22*	Aug 4	Aug 17
Air Temp.	16.0	19.0	14.8	11.0	22.0	19.5	20.0							
Depth, m														
Surface	10.0	16.0	15.0	15.0	18.0	17.5	17.0	13.6	10.2	9.8	8.0		8.8	8.5
1	10.0	13.0	15.0	15.0	18.0	17.5	17.0	13.6	10.4	9.5	8.0		9.2	8.6
2	9.0	13.0	15.0	15.0	17.0	17.5	17.0	13.7	10.4	9.5	8.0		9.1	8.6
3	8.0	12.5	15.0	15.0	17.0	17.5	17.0	13.8	10.6	9.5	7.9		9.0	8.5
4	6.0	12.5	15.0	15.0	17.0	17.5	17.0	13.8	10.6	9.5	7.9		8.6	8.5
5	6.0	12.5	15.0	15.0	17.0	17.0	17.0	13.7	10.6	9.5	7.9		8.5	8.4
6	6.0	12.0	15.0	15.0	16.5	17.0	17.0	13.6	10.6	9.5	7.9		8.6	8.4
7	5.5	12.0	15.0	15.0	16.5	17.0	17.0	13.6	10.6	9.5	7.9		8.6	8.4
8	5.5	12.0	14.5	15.0	16.0	17.0	17.0	13.6	10.6	9.2	7.9		8.5	8.4
9	5.5	12.0	14.0	15.0	16.0	17.0	17.0	13.6	10.6	9.0	7.8		8.5	8.4
10	5.5	12.0	13.5	15.0	16.0	17.0	17.0	13.6	10.4	8.7	7.8		8.1	8.4
11	5.5	12.0	12.5	15.0	16.0	17.0	17.0	13.4	10.2	8.2	7.8		8.0	8.3
12	5.5	10.0	12.5	15.0	16.0	17.0	17.0	13.4	9.8	8.1	7.6		8.0	8.3
13	5.5	9.5	12.0	15.0	15.5	17.0	17.0	13.4	9.5	7.8	7.6		7.5	8.3
14	5.0	9.0	11.0	15.0	16.0	16.5	17.0	13.3	9.2	7.1	7.6		7.3	8.3
15	5.0	8.5	11.0	15.0	16.0	16.5	17.0	13.3	9.0	7.0	7.6		6.6	8.2
16	5.0	8.5	11.0	15.0	15.5	16.5	17.0	13.3	8.7	6.9	7.6		6.4	8.2
17	5.0	8.0	11.0	15.0	15.5	16.0	17.0	13.3	8.7	6.4	7.6	7.6	5.2	8.1
18	5.0	8.0	10.5	15.0	15.5	16.0	16.5	13.3	8.3	6.0	7.6	7.3	4.3	6.7
19	5.0	8.0	10.0	15.0	15.0	15.5	16.5	13.3	8.3	5.4	7.6	4.8	3.8	6.6
20	5.0	8.0	10.0	15.0	14.5	15.5	16.0	13.3	8.2	5.0	7.4	3.3	3.4	5.8
21	5.0	8.0	10.0	14.0	14.0	15.5	16.0	13.4	8.1	4.6	5.3	1.9	2.8	5.5
22	5.0	8.0	9.0	13.0	13.0	15.5	16.0	13.4	8.1	4.0	3.8	0.7	2.6	5.4
23	5.0	7.5	9.0	12.0	13.0	15.0	16.0	13.4	8.0	3.9	2.7	0.6	2.5	5.4
24	5.0	7.5	9.0	12.0	13.0	15.0	16.0	13.4	8.0	3.8	2.0	0.5	1.8	5.4
25	5.0	7.5	9.0	12.0	12.5	15.0	16.0	13.4	7.9	3.8	1.8	0.5	1.2	5.4
26	5.0	7.0	9.0	11.0	12.5	14.5	16.0	13.4	7.8	3.8	1.3	0.5	0.9	4.3
27	5.0	7.0	9.0	11.0	12.0	14.0	16.0	13.4	7.6	3.8	1.2	0.5	0.4	3.4
28	5.0	7.0	9.0	11.0	12.0	13.5	15.5	13.4	7.5	3.8	1.0	0.5	0.4	2.6

Appendix 1. Limnological observations at Station A, Smoothstone Lake, 1988. See Fig. 2 for station locations. (Continued)

	Temperature, C							Dissolved oxygen, mg/L						
	May 25	June 10	June 24	July 9	July 22	Aug 4	Aug 17	May 25	June 10	June 24	July 9	July 22*	Aug 4	Aug 17
29	5.0	7.0	9.0	11.0	12.0	13.0	15.0	13.3	7.5	2.8	0.8	0.5	0.5	0.4
30	5.0	7.0	9.0	11.0	11.8	12.5	13.0	13.2	7.4	2.8	0.5	0.5	0.5	0.5
31	5.0	7.0		10.0	11.5	12.0	12.0	13.2	7.3		0.4	0.5	0.5	0.6
32				10.0							0.4			
Station depth, m		32.5	31.0	34.0	34.0	35.0	32.0							
pH														
Surface	8.3	8.2	8.2	8.0	8.2	8.2	8.1							
Bottom	8.1	7.8	7.8	7.3	7.4	7.4	7.4							
Secchi depth, m	4.0	3.0	3.5	2.2	2.5	2.2	2.0							

* Oxygen meter malfunctioning

Appendix 2. Limnological observations at Station B, Smoothstone Lake, 1988. See Fig. 2 for station locations.

	Temperature, C							Dissolved oxygen, mg/L						
	May 26	June 10	June 24	July 9	July 22	Aug 4	Aug 18	May 26	June 10	June 24	July 9	July 22	Aug 4	Aug 18
Air Temp.	14.0	18.0	14.8	13.5	21.0	21.0	19.0							
Depth, m														
Surface	8.5	13.0	15.6	15.8	19.0	18.0	17.5	12.0	10.9	10.8	8.3	12.2	10.2	10.4
1	8.5	12.5	15.6	15.8	18.0	18.0	17.5	12.0	11.3	10.0	8.3	9.9	10.0	10.0
2	8.0	12.5	15.6	15.8	18.0	18.0	17.5	12.0	11.4	10.0	8.3	9.8	10.0	10.0
3	8.0	12.5	15.6	15.8	18.0	18.0	17.5	12.0	11.3	10.0	8.2	10.0	9.3	10.0
4	7.5	12.5	15.5	15.8	18.0	18.0	17.5	12.0	11.3	10.1	8.2	9.9	9.6	10.0
5	7.5	12.5	15.5	15.7	18.0	17.5	17.0	12.0	11.3	10.6	8.2	9.8	9.3	10.0
6	7.0	12.5	15.3	15.7	17.5	17.5	17.0	12.0	11.2	10.5	8.2	9.7	9.0	9.6
7	7.0	12.0	15.3	15.7	16.5	17.5	17.0	11.9	11.2	10.4	8.2	9.8	9.0	9.6
8	7.0	12.0	15.0	15.6	16.5	17.0	17.0	11.8	11.2	10.4	8.2	9.6	8.8	9.4
9	7.0	12.0	15.0	15.6	16.5	17.0	17.0	11.8	11.1	10.4	8.2	9.6	8.5	9.6
10	7.0	12.0	14.2	15.6	16.0	17.0	17.0	11.7	11.0	10.0	8.2	8.8	8.2	9.3
11	6.5	11.5	13.2	15.6	15.5	17.0	17.0	11.7	10.8	9.8	8.1	7.6	8.1	9.4
12	6.5	11.5	12.5	15.6	15.0	16.5	17.0	11.6	10.7	9.7	8.1	7.2	7.3	9.1
13	6.5	11.5	11.8	15.5	15.0	16.0	17.0	11.6	10.6	9.0	7.9	7.1	6.6	8.9
14	6.0	11.0	11.0	15.1	15.0	16.0	16.5	11.5	10.5	8.6	7.4	7.0	6.5	7.8
15	6.0	11.0	10.6	14.9	15.0	16.0	16.5	11.4	10.5	7.6	6.5	6.9	6.4	6.3
16	6.0	10.5	10.0	14.7	15.0	15.5	16.2	11.2	10.2	6.8	6.3	6.6	5.6	5.6
17	6.0	10.5	9.2	14.4	15.0	15.0	16.0	11.2	10.2	5.6	6.2	6.2	4.9	4.8
18	5.5	10.0	8.8	13.4	14.0	14.0	15.0	10.8	9.9	4.6	5.2	4.5	2.1	3.1
19	5.0	7.5	8.8	12.0	13.0	13.5	14.0	10.4	8.0	4.3	2.0	2.8	1.1	0.3
20	5.0	7.0	8.8	11.0	11.5		13.5	10.0	7.8	4.3	0.5	0.5		0.3
21	5.0	6.0							7.2					
Station depth, m	22.0	22.0	22.0	22.0	22.0	22.5	21.0							
pH														
Surface	8.3	8.2	8.2	8.1	8.3	8.3	8.2							
Bottom	8.1	7.8	7.4	7.8	7.3	7.5	7.4							
Secchi depth, m	2.6	3.5	3.0	2.2	2.0	1.5	2.0							

Appendix 3. Relative abundance (no. cells x 1000/L) of plankton in Smoothstone Lake, 1988.

Station	A	A	A	A	A	A	B	B	B	B
Date	May 25	June 23	July 8	July 22	Aug 4	Aug 17	May 20	June 10	July 8	Aug 17
CHLOROPHYCEAE (Green algae)										
Closterium	0.00	0.00	0.00	0.10	0.04	0.00	0.04	0.04	0.00	0.00
Coelastrum microporum	0.00	0.00	0.00	0.80	1.00	1.00	0.00	0.00	0.80	0.00
Crucigenia quadrata	1.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
Crucigenia tetrapedia	0.00	0.40	0.80	0.80	0.80	0.80	0.00	0.00	0.40	1.00
Elakatothrix gelatinosa	0.00	0.00	0.40	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Gonium pectorale	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.10	0.00
Oocystis borgei	0.10	1.00	0.50	1.00	0.20	0.80	0.00	0.40	0.40	0.50
Pediastrum boryanum	2.80	1.80	2.00	2.00	2.00	2.40	0.00	1.80	3.00	2.00
Pediastrum duplex	2.00	1.00	1.80	1.00	1.40	2.00	0.00	1.00	2.80	2.40
Pediastrum obtusum	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.50	1.00
Quadrigula chodatii	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.10	0.00
Scenedesmus acuminatus	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	1.00	0.80
Scenedesmus bijuga	0.00	0.00	0.00	0.00	0.50	1.00	0.00	0.00	0.00	0.80
Scenedesmus ecornis	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.80	1.20
Scenedesmus quadricauda	0.00	1.00	0.80	0.20	0.80	0.80	0.00	0.08	0.80	1.00
Selenastrum gracillimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Staurastrum	0.00	0.08	1.00	0.20	0.20	0.20	1.10	0.08	0.40	0.80
TOTAL	5.90	5.28	8.50	6.20	8.04	9.88	1.14	3.40	12.10	11.50
CHRYSOPHYCEAE (Golden algae)										
Dinobryon sertularia	0.40	1.00	0.50	1.00	1.00	0.00	0.80	0.00	0.20	0.80
Mallomonas acuroides	0.40	0.10	0.10	0.40	0.20	0.50	0.08	0.50	0.40	0.40
TOTAL	0.80	1.10	0.60	1.40	1.20	0.50	0.88	0.50	0.60	1.20
BACILLARIOPHYCEAE (Diatoms)										
Amphora	0.00	0.04	0.04	0.00	0.00	0.04	0.04	0.00	0.04	0.08
Asterionella formosa	0.00	1.20	1.00	1.00	1.00	0.80	0.80	1.40	0.80	0.40
Cocconeis pediculus	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.08
Diatoma	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.80	0.00	0.00
Fragilaria crotonensis	1.40	2.40	3.40	2.40	2.80	2.80	1.20	2.20	3.20	3.00
Melosira granulata	0.80	1.20	1.80	1.00	1.60	1.40	0.00	1.00	1.80	1.40
Navicula	0.08	0.04	0.00	0.10	0.08	0.08	0.08	0.08	0.08	0.04
Nitzschia acicularis	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.04	0.04
Rhopalodia gibba	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.04	0.00

Appendix 3. Relative abundance (no. cells x 1000/L) of plankton in Smoothstone Lake, 1988. (Continued)

Station	A	A	A	A	A	A	B	B	B	B
Date	May 25	June 23	July 8	July 22	Aug 4	Aug 17	May 20	June 10	July 8	Aug 17
Stephanodiscus astrea	1.00	1.40	1.20	0.80	0.40	1.00	1.00	0.80	1.00	0.80
Surirella oblonga	0.04	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Synedra acus	0.00	0.80	0.10	0.20	0.00	0.20	0.00	0.10	0.08	0.20
Synedra ulna	0.10	0.50	0.50	0.10	0.08	0.20	0.80	0.50	0.10	0.40
Tabellaria fenestrata	1.20	1.20	1.80	1.40	1.80	1.20	1.00	1.00	0.80	1.00
TOTAL	4.70	8.78	9.84	7.40	8.04	7.84	4.92	7.88	8.02	7.44
EUGLENOPHYCEAE (Euglenoids)										
Euglena	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.00
Phacus	0.04	0.04	0.04	0.00	0.08	0.00	0.04	0.00	0.00	0.00
TOTAL	0.04	0.04	0.04	0.04	0.08	0.00	0.04	0.04	0.00	0.00
DINOPHYCEAE (dinoflagellates)										
Ceratium hirundinella	0.04	0.08	0.04	0.80	0.20	0.08	0.00	0.10	0.08	0.10
Gymnodinium	0.10	0.10	0.20	0.10	0.40	0.00	0.10	0.40	0.08	0.00
Peridinium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Dinoflagellate cysts	0.00	0.00	0.40	0.10	0.00	0.08	0.00	0.08	0.10	0.08
TOTAL	0.14	0.18	0.64	1.00	0.60	0.16	0.10	0.58	0.30	0.18
MYXOPHYCEAE (Blue-green algae)										
Anabaena flos-aqua	1.00	2.40	2.00	1.00	2.40	2.00	2.00	2.40	1.60	3.00
Aphanizomenon flos-aqua	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.20	0.00	0.00
Aphanocapsa	0.00	0.00	0.00	2.40	0.00	0.00	0.00	0.00	0.00	0.00
Chroococcus limneticus	0.50	0.40	0.50	1.50	1.00	1.00	0.50	0.80	1.00	0.80
Coelosphaerium kuetzingianum	0.00	0.00	0.00	0.00	2.00	2.00	0.00	0.00	3.00	3.00
Coelosphaerium naegelianum	2.00	4.00	5.00	5.00	3.50	4.50	2.50	3.80	4.50	6.00
Merismopedia tenuissima	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00
Microcystis aeruginosa	6.00	12.00	10.00	14.00	10.00	14.00	8.00	4.50	18.00	22.00
Oscillatoria	0.00	0.80	0.00	0.40	0.00	0.00	1.00	0.00	0.00	0.00
TOTAL	10.50	19.60	17.50	25.10	19.90	23.50	14.00	12.70	28.10	34.80

Appendix 3. Relative abundance (no. cells x 1000/L) of plankton in Smoothstone Lake, 1988. (continued)

Station	A	A	A	A	A	A	B	B	B	B
Date	May 25	June 23	July 8	July 22	Aug 4	Aug 17	May 20	June 10	July 8	Aug 17
TOTAL	22.08	34.98	37.12	41.14	37.86	41.88	21.08	25.10	49.12	57.12
UNIDENTIFIED FLAGELLATES	0.40	0.80	0.80	1.40	0.50	1.20	0.50	1.00	1.00	1.80
ROTATORIA										
Keratella cochlearis	0.08	0.10	0.04	0.00	0.04	0.04	0.00	0.00	0.04	0.04
COPEPODA										
Cyclops	0.04	0.08	0.08	0.04	0.00	0.04	0.04	0.00	0.04	0.04
TOTAL	0.12	0.18	0.12	0.04	0.04	0.08	0.04	0.00	0.08	0.08

Appendix 4. Numbers and weights of organisms taken by dredging (523 cm Ekman), Smoothstone Lake, 1988.

	June						June					
Series No.	1	1	1	1	1	1	2	2	2	2	2	2
Dredge No.	1	2	3	4	5	6	1	2	3	4	5	6
Oligochaeta	1	13	29	8	12	2	2	92	23	9	2	1
Amphipoda	4	0	0	0	0	0	1	1	4	0	2	2
Ephemeroptera	0	0	0	0	0	0	1	0	0	0	0	1
Ceratopogonidae	0	0	0	0	0	0	0	1	1	1	0	0
Chironomidae	16	41	45	69	35	7	8	73	59	100	41	37
Sphaeriidae	2	3	2	1	2	1	3	13	3	0	1	4
Total	23	57	76	78	49	10	15	180	90	110	46	45
Wet weight less mollusc shells, mg	40	80	500	700	520	50	30	420	780	1150	310	220
Depth, m	1.8	9.0	10.6	12.0	10.0	7.3	1.5	2.2	6.0	8.0	4.5	2.6

	June 11						June 11					
Series no.	3	3	3	3	3	3	4	4	4	4	4	4
Dredge no.	1	2	3	4	5	6	1	2	3	4	5	6
Oligochaeta	28	16	8	19	22	17	1	0	5	17	8	0
Hirudinea	0	0	0	0	0	3	0	0	0	0	0	0
Amphipoda	91	50	0	110	0	19	0	1	0	0	0	0
Ephemeroptera	1	0	0	0	0	0	1	0	0	0	2	0
Trichoptera	2	1	0	1	1	0	0	0	0	0	0	0
Ceratopogonidae	0	1	0	1	0	0	0	0	0	0	1	0
Chironomidae	62	21	49	80	40	105	3	24	54	31	24	10
Gastropoda	0	19	0	4	0	0	0	0	0	0	0	0
Sphaeriidae	23	0	13	11	65	27	1	0	0	0	0	1
Unidentified	1	0	0	0	0	0	0	0	0	1	2	0
Total	208	108	70	226	128	171	6	25	59	49	37	11
Wet weight less mollusc shells, mg	60	40	910	470	320	670	10	50	1170	1200	920	160
Depth, m	3.0	2.5	2.5	3.0	3.1	10.0	2.5	5.5	21.0	15.0	13.5	6.2

Appendix 4. Numbers and weights of organisms taken by dredging (523 cm Ekman), Smoothstone Lake, 1988. (continued)

	June 23						June 23					
Series No.	5	5	5	5	5	5	6	6	6	6	6	6
Dredge no.	1	2	3	4	5	6	1	2	3	4	5	6
Oligochaeta	1	5	18	21	6	11	4	8	9	6	21	0
Ephemeroptera	0	0	0	0	0	0	0	0	0	0	0	1
Ceratopogonidae	1	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	4	82	21	47	34	87	32	10	34	13	61	1
Sphaeriidae	0	7	0	0	2	4	5	1	0	0	0	1
Unidentified	0	1	0	0	0	0	1	1	0	2	1	0
Total	6	95	39	68	42	102	42	20	43	21	83	3
Wet weight less mollusc shells, mg	5	150	940	970	930	260	100	20	850	510	1470	10
Depth, m	2.0	10.0	13.5	15.0	15.5	10.0	7.5	9.1	21.0	25.0	23.0	4.0

	June 24						June 25					
Series no.	7	7	7	7	7	7	8	8	8	8	8	8
Dredge no.	1	2	3	4	5	6	1	2	3	4	5	6
Oligochaeta	1	16	0	13	24	8	0	1	0	2	3	5
Amphipoda	2	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	0	0	0	0	0	0	0	1	0	0	0	0
Trichoptera	2	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	2	40	2	9	27	36	0	4	1	5	1	21
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	2
Total	7	56	2	22	51	44	0	6	1	7	4	28
Wet weight less mollusc shells, mg	60	140	1	70	10	1040	0	10	1	70	1	80
Depth, m	1.7	8.0	7.5	22.8	10.9	2.5	4.5	11.5	16.5	23.0	23.0	15.0

Appendix 4. Numbers and weights of organisms taken by dredging (523 cm Ekman), Smoothstone Lake, 1988. (continued)

	July 11						July 13					
Series no.	9	9	9	9	9	9	10	10	10	10	10	10
Dredge no.	1	2	3	4	5	6	1	2	3	4	5	6
Oligochaetae	0	1	0	3	8	13	5	2	0	46	4	5
Hirudinea	0	0	0	0	0	0	1	0	0	1	0	0
Amphipoda	0	0	0	0	0	0	3	0	0	4	2	0
Ephemeroptera	0	0	0	1	0	0	2	0	0	1	0	0
Chironomidae	0	0	0	10	17	3	53	3	0	36	32	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	2
Unidentified	0	0	0	1	0	0	0	0	0	2	0	5
Total	0	1	0	15	25	16	64	5	0	90	38	12
Wet weight less mollusc shells, mg	0	0	0	90	560	20	70	5	0	1510	1220	5
Depth, m	7.0	25.0	10.0	15.0	17.0	7.0	3.5	9.5	9.5	17.0	14.5	7.5

	July 13						August 3					
Series No.	11	11	11	11	11	11	12	12	12	12	12	12
Dredge No.	1	2	3	4	5	6	1	2	3	4	5	6
Oligochaeta	0	6	0	1	2	0	0	7	4	4	4	4
Hirudinea	1	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	4	0	0	0	0	0	0	1	1	3	0	1
Coleoptera	0	0	0	0	0	0	0	0	0	0	1	0
Ephemeroptera	0	0	0	0	0	1	0	0	0	0	0	0
Trichoptera	3	0	0	0	0	0	0	0	0	0	1	0
Ceratopogonidae	0	0	0	0	0	1	0	0	0	0	0	0
Chironomidae	32	41	2	3	0	1	1	2	0	12	30	3
Gastropoda	0	0	0	0	0	0	0	0	0	0	0	1
Sphaeriidae	0	0	0	0	0	0	0	1	0	0	0	0
Unidentified	0	2	0	0	0	0	0	0	0	0	0	0
Total	40	49	2	4	2	3	1	11	5	19	36	9
Wet weight less mollusc shells, mg	220	890	0	5	0	10	0	60	0	50	40	20
Depth, m	2.0	17.0	10.0	6.0	16.0	6.5	7.5	20.0	21.0	16.5	11.5	9.0

Appendix 4. Numbers and weights of organisms taken by dredging (523 cm Ekman), Smoothstone Lake, 1988. (continued)

	August 5					
Series No.	13	13	13	13	13	13
Dredge No.	1	2	3	4	5	6
Oligochaeta	5	1	2	1	1	8
Amphipoda	0	1	0	0	0	0
Ephemeroptera	0	0	0	0	0	2
Chironomidae	4	6	7	3	2	15
Gastropoda	0	0	0	0	0	1
Sphaeriidae	3	1	2	1	1	2
Total	12	9	11	5	4	28
Wet weight less mollusc shells, mg	20	30	60	40	10	120
Depth,	3.5	19.0	19.0	19.0	19.0	4.5

Appendix 5. Gillnet summary, Smoothstone Lake, 1988

Net Set	Burbot		Cisco		White Sucker		Longnose Sucker		Perch		Pike		Walleye		Whitefish		Total	
	No.	Wt,kg	No.	Wt,kg	No.	Wt,kg	No.	Wt,kg	No.	Wt,kg	No.	Wt,kg	No.	Wt,kg	No.	Wt,kg	No.	Wt,kg
1	5	9.6	23	0.9	70	35.5	42	26.1	38	0.8	9	17.1	0	0.0	14	15.1	201	105.1
2	0	0.0	0	0.0	69	53.8	7	8.8	11	0.5	39	48.5	0	0.0	7	5.4	133	117.0
3	0	0.0	0	0.0	15	7.1	3	1.4	66	2.8	1	1.6	0	0.0	11	14.4	96	27.3
4	1	2.5	19	0.9	111	40.7	20	12.0	6	0.4	0	0.0	0	0.0	11	6.4	168	62.9
5	0	0.0	0	0.0	76	31.3	8	7.5	11	0.4	0	0.0	0	0.0	3	1.3	98	40.5
6	0	0.0	0	0.0	35	28.2	9	6.3	31	1.6	31	52.2	0	0.0	1	0.1	88	88.4
7	0	0.0	34	1.6	164	52.3	2	1.1	10	0.4	2	1.2	0	0.0	1	0.1	213	56.7
8	3	6.8	44	2.0	60	29.5	139	106.8	2	0.1	1	2.2	0	0.0	27	5.2	276	152.6
9	0	0.0	0	0.0	64	55.9	5	4.9	0	0.0	36	56.0	0	0.0	4	2.4	109	119.2
10	0	0.0	24	1.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	15	8.1	39	9.2
11	0	0.0	11	0.6	31	13.3	34	25.5	101	4.9	0	0.0	0	0.0	13	7.2	190	51.5
12	0	0.0	12	0.6	2	1.1	91	45.1	31	1.2	0	0.0	0	0.0	128	62.2	264	110.2
13	0	0.0	1	0.1	46	16.6	0	0.0	15	1.3	0	0.0	0	0.0	5	0.4	67	18.4
14	1	0.9	26	1.2	18	7.2	20	17.8	2	0.1	0	0.0	0	0.0	36	14.1	103	41.3
15	0	0.0	26	1.1	262	94.5	20	11.1	72	3.3	1	0.3	0	0.0	9	5.4	390	115.7
16	2	3.0	2	0.1	42	22.1	1	0.8	8	0.4	1	2.2	0	0.0	2	0.8	58	29.4
17	0	0.0	6	0.3	62	20.8	11	6.9	57	3.0	0	0.0	0	0.0	2	2.0	138	33.0
18	0	0.0	0	0.0	43	38.5	7	5.9	11	0.6	14	17.2	0	0.0	8	6.8	83	69.0
19	1	0.5	9	0.4	26	5.7	32	14.4	50	2.0	0	0.0	1	0.1	9	4.5	128	27.6
20	0	0.0	7	0.3	70	23.1	11	7.9	71	4.6	0	0.0	0	0.0	9	0.6	168	36.5
21	0	0.0	47	2.0	43	14.1	177	33.7	126	5.9	0	0.0	0	0.0	166	75.7	559	131.4
22	4	8.3	10	0.4	59	11.4	19	3.3	63	2.9	0	0.0	0	0.0	14	5.1	169	31.4
23	4	10.8	103	4.6	26	4.7	8	2.5	56	2.4	0	0.0	0	0.0	28	11.8	225	36.8
24	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.8	1	0.8
25	0	0.0	12	0.5	0	0.0	36	20.2	24	0.9	0	0.0	0	0.0	85	29.4	157	51.0
26	0	0.0	1	0.1	31	19.6	21	20.4	33	1.5	7	10.4	0	0.0	1	0.1	94	52.1
Total	21	42.4	417	18.8	1425	627.0	723	390.4	895	42.0	142	208.9	1	0.1	610	285.4	4234	1615.0
Avg /Set	0.8	1.6	16.0	0.7	54.8	24.1	27.8	15.0	34.4	1.6	5.5	8.0	<0.1	<0.1	23.5	11.0	162.9	62.1
% of total	0.5	2.6	9.8	1.2	33.7	38.8	17.1	24.2	21.1	2.6	3.4	12.9	<0.1	<0.1	14.4	17.7	100.0	100.0

Appendix 6. Fish catch distribution in various mesh sizes of gillnets used in Smoothstone Lake, 1988.

	Number of fish							Weight, kg						
Mesh size, cm	3.8	5.1	7.6	10.2	12.7	14.0	Total	3.8	5.1	7.6	10.2	12.7	14.0	Total
Burbot	0	0	2	3	5	11	21	0.0	0.0	0.8	3.6	10.1	27.9	42.4
Cisco	390	5	12	2	6	2	417	17.6	0.3	0.5	0.1	0.2	0.1	18.8
White sucker	171	337	713	176	3	25	1425	13.2	53.3	379.0	156.2	2.4	22.9	627.0
Longnose sucker	71	191	242	168	31	20	723	7.1	38.6	151.8	140.7	32.3	19.9	390.4
Perch	815	68	10	1	0	1	895	36.0	5.6	0.2	0.1	0.0	0.1	42.0
Pike	8	46	59	28	0	1	142	10.8	58.9	85.6	52.3	0.0	1.3	208.9
Walleye	1	0	0	0	0	0	0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Whitefish	80	100	259	130	22	14	610	9.3	23.2	128.0	89.5	23.8	11.6	285.4
Total	1541	747	1297	508	67	74	4234	94.1	179.9	745.9	442.5	68.8	83.8	1615.0

Appendix 7. Analysis of organisms found in 142 pike captured in Smoothstone Lake, 1988.

Organism	% Composition by volume
Insects:	
Chironomidae	0.5
Ephemeroptera	2.9
Amphipoda	0.6
Fish remains:	
Stickleback	21.4
Cisco	11.9
Perch	10.3
Trout-perch	10.3
White sucker	9.5
Whitefish	1.6
Darter	1.6
Burbot	0.8
Unidentified	27.0
Fish eggs	1.6
No. of stomachs examined	142
% with food	39.6

Appendix 8. Maturity stages of whitefish from Smoothstone Lake, 1988.

Fork length, cm	Female			%	Male			%
	Immature	Mature	Total	Mature	Immature	Mature	Total	Mature
16.1-18.0	13	0	13	0	3	0	3	0
18.1-20.0	13	0	13	0	4	0	4	0
20.1-22.0	15	1	16	6.3	10	1	11	9.1
22.1-24.0	5	0	5	0	5	2	7	28.6
24.1-26.0	4	4	8	50.0	5	2	7	28.6
26.1-28.0	12	0	12	0	7	0	7	0
28.1-30.0	19	2	21	9.5	9	1	10	10.0
30.1-32.0	11	8	19	42.1	5	0	5	0
32.1-34.0	5	10	15	66.7	1	0	1	0
34.1-36.0	3	27	30	90.0	0	3	3	100.0
36.1-38.0	2	45	47	95.8	0	7	5	100.0
38.1-40.0	0	23	23	100.0	0	3	3	100.0
40.1-42.0	0	5	5	100.0	0	2	2	100.0
42.1-44.0	0	4	4	100.0	0	3	3	100.0
44.1-46.0	0	2	2	100.0	0	2	2	100.0
46.1-48.0	0	1	1	100.0	0	1	1	100.0
48.1-50.0	0	2	2	100.0	0	1	1	100.0
50.1-52.0	0	1	1	100.0	0	1	1	100.0
54.1-56.0	0	1	1	100.0				

Calculation of size at maturity by the equation (Ni and Sandeman 1984):

$$\ln \frac{P}{100-P} = \alpha + \beta L$$

-where P is percent mature, L is length (using centre of each length class);
-size at maturity, $L_{(50)}$, is defined as the size at which 50% of the fish have reached their sexual maturity;
$L_{(50)} = -\alpha/\beta$

Female: $L_{(50)} = -\alpha/\beta = 13.478/0.478 = 28.5$ cm

Male: $L_{(50)} = -\alpha/\beta = 15.131/0.572 = 26.5$ cm

Appendix 9. Analysis of organisms found in 407 whitefish captured by gillnetting in Smoothstone Lake, 1988.

Organism	% Composition by volume
Insects:	
Chironomidae	64.4
Chaoboridae	0.2
Ceratopogonidae	0.2
Unidentified Diptera	0.1
Corixidae	1.0
Trichoptera	0.4
Ephemeroptera	0.4
Zygoptera	0.2
Coleoptera	0.1
Unidentified	1.2
Nematomorpha	0.2
Amphipoda	2.2
Ostracoda	1.0
Sphaeriidae	18.7
Gastropoda	1.3
Fish remains:	
Perch	0.8
Stickleback	1.1
Cisco	0.4
Unidentified	4.0
Plant material	2.1
No. of stomachs examined	407
% with food	61.4

Appendix 10. Commercial production in Smoothstone Lake.

Year	Weight, kg					No. Lic.
	Whitefish	Walleye	Pike	Other	Total	
1925-26	12519	1043	2631	1225	17418	16
1926-27	4466	125	227	234	5051	4
1927-28	1851	123	312	4644	6929	1
1929-30	17373	0	45	820	18237	4
1930-31	5126	0	1	0	5127	7
1931-32	20593	1814	1814	3039	27261	0
1932-33	20593	1814	1814	3447	27670	7
1936-37	8105	66	0	1996	10166	6
1940-41	2041	23	9	454	2527	1
1941-42	15704	10755	1443	5548	33450	9
1942-43	14604	25594	3392	4022	47611	8
1943-44	83384	44974	6695	8638	143691	29
1944-45	31187	19213	3271	3865	57536	22
1945-46	126244	1032	888	1034	129198	30
1946-47	5274	4226	213	100	9813	9
1947-48	54612	1127	69	399	56207	5
1949-50	17710	91	136	1361	19297	6
1950-51	544	9103	5978	4213	19838	6
1951-52	14268	15811	14752	6441	51272	11
1952-53	8256	1270	4949	1783	16257	6
1953-54	68	2014	104	454	2640	2
1957-58	89	528	755	0	1373	2
1959-60	2268	2084	0	0	4352	5
1960-61	1799	2527	1455	0	5781	9
1962-63	3115	17993	4854	30391	56353	10
1963-64	5260	5993	554	0	11807	8
1964-65	181	14	635	4495	5325	4
1965-66	0	38	93	0	131	2
1966-67	79	2308	1281	0	3668	3
1967-68	2892	3283	4361	91	10627	12
1968-69	7284	2437	5766	89	15575	11
1969-70	55	535	660	0	1250	8
1970-71	8266	468	8825	0	17559	28
1971-72	6284	350	7722	0	14356	21
1972-73	1025	116	1693	22680	25519	6
1973-74	675	62	2068	0	2805	5
1974-75	2419	45	2160	2268	6891	10
1975-76	828	465	5748	0	7041	5
1976-77	681	95	1561	0	2336	6
1977-78	25	110	3771	0	3906	5
1978-79	138	210	4127	0	4475	4

Appendix 10. Commercial production in Smoothstone Lake. (continued)

Year	Weight, kg					No.
	Whitefish	Walleye	Pike	Other	Total	Lic.
1979-80	530	1356	9140	0	11026	5
1980-81	769	1368	1784	0	3920	10
1981-82	376	286	4069	0	4731	7
1982-83	1008	118	7890	14	9030	7
1983-84	911	382	7760	0	9053	7
1984-85	567	2453	6002	0	9022	7
1985-86	697	1884	2116	0	4697	6
1986-87	2917	2140	9369	0	14426	9
1987-88	1976	415	7465	0	9856	6
1988-89	2370	149	8296	0	10815	8
Total	520006	190430	170723	113745	994902	425
Average	10196	3734	3348	2230	19507	8
%	52.3	19.1	17.2	11.4		
kg/ha	0.37	0.13	0.12	0.08	0.70	0.00